ORDER

6580.3A

REMOTE COMMUNICATIONS FACILITIES INSTALLATION STANDARDS HANDBOOK

NOVEMBER 1, 1993

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

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CHANGE TO BASIC	SUPPLEMENTS			OPTIONAL USE	CHANGE TO BASIC	SUPPLEMENTS			OPTIONAL USE

FAA FORM 1320–5

FOREWORD

This order provides guidance and reference material to be used in the installation of remote communications facilities, i.e., air-to-ground radio communications facilities, in support of the Capital Investment Plan.

This order also outlines the orderly approach leading to the establishment, reconsolidation, relocation, and upgrade of remote communications facilities. Every effort was made to consider those activities required with tasks to be completed first, followed with tasks to be completed in a finished operational remote communications facility.

The expected results of establishing a complete standards guide to be followed by all regions includes cost avoidance through: (1) improved grounding and bonding requirements; (2) reduced maintenance travel and staff time; and (3) reduced retrofitting for implementation of modern equipment.

An earnest attempt was made to include all related information needed to establish or improve remote communications facilities. Ideas to enhance or expand the handbook to be a more useful and beneficial tool are greatly appreciated. Additional information which only those persons with direct hands-on experience can provide should be conveyed to ANC-300 by calling (202) 287-7181 or writing to Program Manager for Air/Ground Communications and Control Program, ANC-300, 800 Independence Avenue SW, Washington DC 20591.

Lockett K. Yee

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Program Manager for Air/Ground Communications and Control

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CHAPTER 1. GENERAL

1. **PURPOSE**. This order provides procedures, guidance, and reference material which shall be used in the installation of Remote Communications Facilities (RCF), i.e, air-to-ground (A/G) radio communications facilities, in support of the Capital Investment Plan (CIP) Project 24-02, Communications Facilities Consolidation/Network.

2. **DISTRIBUTION**. This order is distributed to division level in the Office of the Program Director for Communications and Aircraft Acquisition, NAS System Engineering, Air Traffic Plans and Requirements, NAS Transition and Implementation, Systems Maintenance and Operational Support Services; branch level to Regional Airway Facilities divisions; director level at the FAA Technical Center and the Mike Monroney Aeronautical Center; limited distribution to Airway Facilities sector field offices, sector field units, and sector field office units.

3. **CANCELLATIONS**. The following orders are canceled:

a. **Order 6580.2**, Remote Communication Facility Siting Criteria Handbook, dated November 12, 1985.

b. **Order 6580.3**, Remote Communication Facility Installation Standards Handbook, dated April 30, 1986.

4. **BACKGROUND**.

a. **Existing System**. The existing system of remote A/G communications facilities was established according to regional requirements for terminal and en route traffic control and flight services. Specific facilities are used to support Radio Frequency (RF) communications between the pilots and control personnel providing these services. Figure 1-1, Existing A/G Radio Communications System, illustrates the existing A/G radio communications system.

b. **Proposed System**. The improvement of A/G communications facilities through establishment, consolidation, relocation, upgrading, and networking of A/G radio communications facilities will provide improved performance of facilities which serve the combined needs of air traffic control (ATC) and flight services. This activity is a major element in the CIP Plan family of A/G radio communications projects. One major objective of projects in this category is to provide a modern, solid-state, remotely monitored radio communications network with improved performance for the FAA.

5. **PHILOSOPHY**. RCF's provide the A/G radio link between pilots and air traffic controllers, Flight Service Stations (FSS), and terminals. These facilities employ transmitters, receivers, antenna systems, remote control units, and associated equipment necessary for the transmission and reception of RF communications. When controlled by an Air Route Traffic Control Center (ARTCC), an RCF is designated as a Remote Center Air to Ground (RCAG); a Remote Transmitter Receiver (RTR) when controlled by an Airport Traffic Control Tower (ATCT) or Terminal Radar Approach Control (TRACON); and a Remote Communications Outlet (RCO) when controlled by an FSS or Automated Flight Service Station (AFSS). Since the three types of remote communications facilities use common technology and have common design requirements, a single installation standards handbook is applicable to all three types. The CIP Project 24-02, Communications Facilities Consolidation/Network, will reduce costs and improve performance through the consolidation of the various types of communications facilities and upgraded installation standards.

a. **Cost**. Consolidation of individual facilities will reduce costs since the use of additional sites results in more land ownership and/or leasing costs and increased time and costs for travel to and from the sites when providing scheduled and unscheduled maintenance. This is in addition to the cost for building maintenance, heating, ventilation and air conditioning (HVAC), and leased landlines.

b. **Performance**. The existing facilities do not provide the desired level of performance with regard to RF coverage, reliability, and Radio Frequency Interference (RFI) standards. Performance will be enhanced when the new installation standards are put into practice. These standards will define proper installation of equipment and grounding systems, Electromagnetic Compatibility (EMC) objectives, and Electromagnetic Interference (EMI) and RFI reduction measures.

c. **Results**. This project will reduce costs and improve performance through the following:

(1) Reduced land and facilities costs.

(2) Reduced maintenance costs.

(3) Reduced HVAC requirements.

(4) Improved installation procedures.

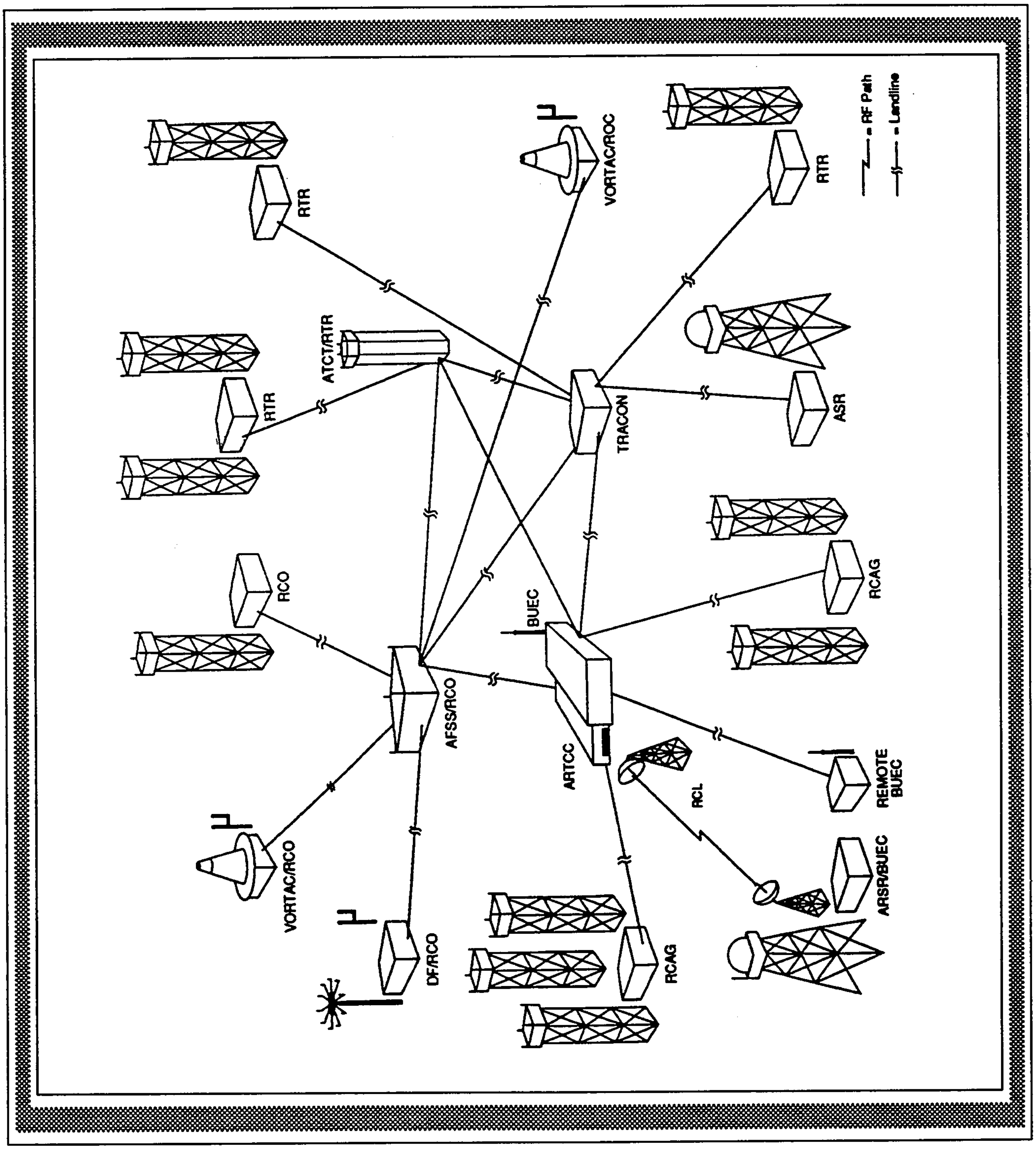
(5) Improved site management.

The consolidated facilities may appear to be a single large facility; however, their individual identities, for the purpose of certain documentation and other non-technical considerations, will be retained. This order contains standard design and installation criteria for communications facilities at consolidated as well as individual stand-alone sites.

6. **SITE CRITERIA**. RCF site relocation, and/or reconfiguration planned by the regions must meet all of the air traffic specified service volume, EMC/EMI/RFI standards, and frequency protection criteria. This will require FAA headquarters and regional spectrum management offices to perform an EMC study, an RFI analysis, and an RF coverage analysis for the frequencies associated with all of the specified service volumes at these sites. It is imperative that the spectrum management offices be involved early in the design process to ensure frequency analysis and frequency assignment process proceeds in a timely manner. Any condition in the RF environment that may affect facility operation must be brought to the attention of the RCF manager and project coordinator. These conditions shall be addressed in the preliminary stages of facility design or relocation.

7.-12. **RESERVED**.

FIGURE 1-1. EXISTING A/G RADIO COMMUNICATIONS SYSTEM



CHAPTER 2. REMOTE COMMUNICATIONS FACILITIES

SECTION 1. GENERAL

13. **REMOTE COMMUNICATIONS FACILITIES OPERATION.** The RCF provide RF communications for various services within the ATC system. The present ATC system is required to provide coverage of the entire airspace over the contiguous United States, Hawaii, Alaska, and the Atlantic and Pacific control zones. This coverage extends from ground surface at terminal areas to an altitude of 70,000 feet at en route areas.

a. **ATC Communications System**. The ATC communications system encompasses a network of ATCT, ARTCC, TRACON, AFSS, FSS, and their associated RCF's. The RCF may be stand-alone or be collocated with other Federal Aviation Administration (FAA)-owned facilities to extend the service range of the ATC facility. The number of stand-alone RCF sites is held to the minimum required to maintain the air traffic coverage. An illustration of a typical ATC A/G radio communications system after consolidation is shown in Figure 2-1, Proposed A/G Radio Communications System.

b. **Terminal A/G Radio Communications Frequencies**. The number of A/G radio communications frequencies for non-approach and non-radar approach control facilities is specific, whereas those for radar approach control facilities vary according to functional requirements.

c. **Terminal Control Facilities**. The terminal control facilities include ATCT, TRACON, AFSS/FSS, and their associated RCF's. A TRACON can be collocated with an ATCT or in a stand-alone facility at the airport. The Air Force RADAR APPROACH CONTROL, and Navy RADAR AIR TRAFFIC CONTROL CENTER are military facilities similar to the FAA TRACON, except that they often have ground-controlled approach capabilities.

(1) **Air Traffic Control Tower**. The upper portion of the tower, called the TOWER CAB, has windows which provide a panoramic view of the airport grounds and airspace in the vicinity. Radar displays which show aircraft location are used by tower personnel for collision avoidance and to position aircraft for landing and takeoff. Control panels for radio communications equipment are located in the tower to provide RF communications between the pilot and ground personnel in the performance of their duties. Figure 2-2, ATCT and Ancillary Facilities, illustrates its principal facilities.

(a) **ATCT Buildings**. The ATCT buildings are frequently leased by the FAA from the local municipality. Current policy permits

FIGURE 2-1. PROPOSED A/G RADIO COMMUNICATIONS SYSTEM

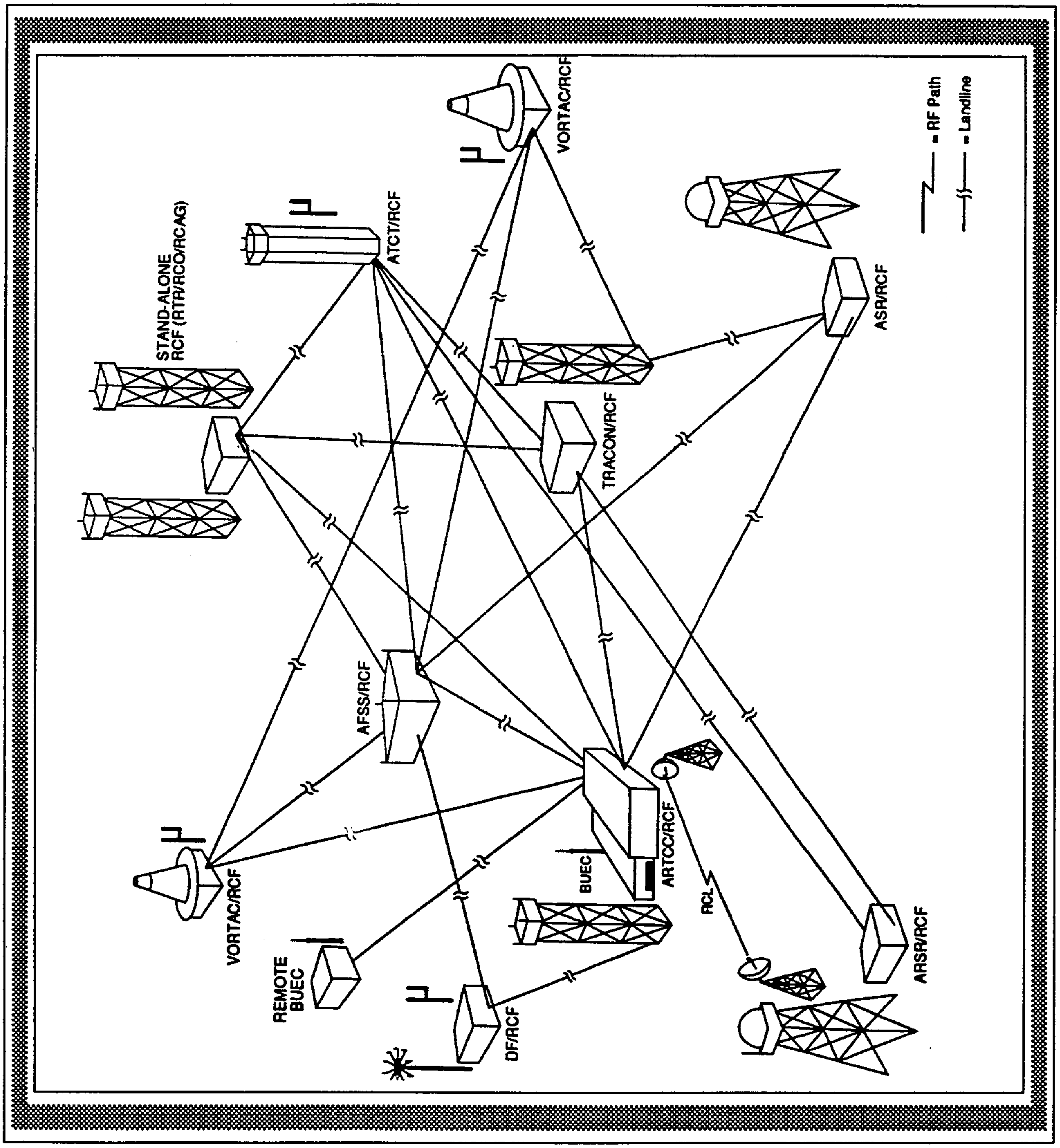
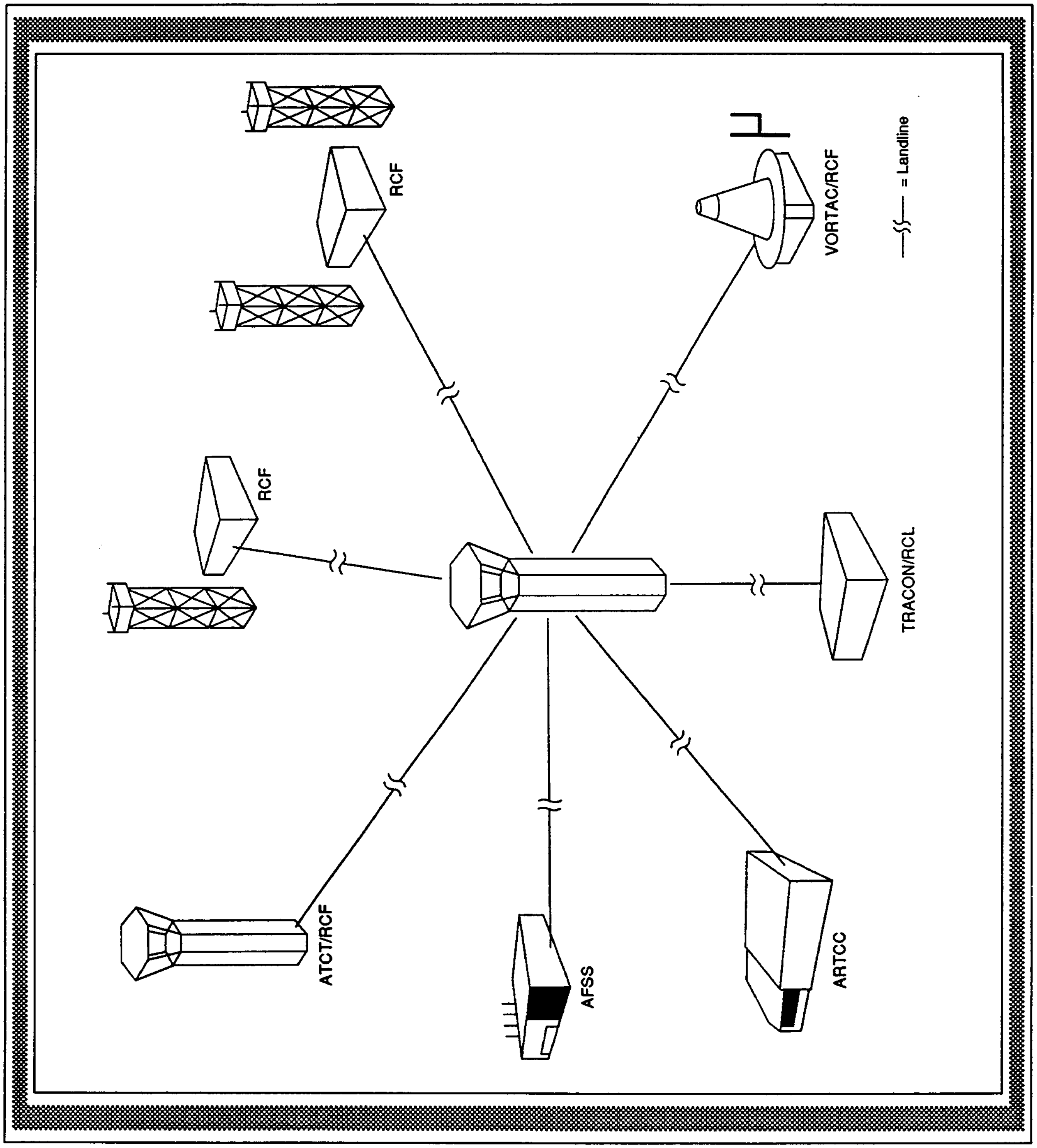


FIGURE 2-2. ATCT AND ANCILLARY FACILITIES



the FAA to construct its own structures, within limitations. The ATCT usually has two or more controller positions, each with its own control and audio equipment. The ATCT building is comprised of a tower cab and in some cases a collocated TRACON, associated equipment room, and administrative offices.

(b) **Tower Cab**. The typical tower cab is located so that a panoramic view of the airport is possible with little or no obstruction. Air traffic controllers work in this space and utilize A/G radio communications, radar, and information from TRACON facilities in the performance of duty. Operations are performed using communications consoles, radar displays, and various indicators and navigational aids.

(c) **Air Traffic Controller**. Air traffic controllers accept aircraft entering their geographic area of responsibility, TRACON/ATCT terminal area or ARTCC sector. They establish A/G radio communications with the aircraft, identify it, and control flight progress until the aircraft is handed over to an adjacent sector or terminal or is released from the control system.

(2) **Terminal Radar Approach Control**. In busy air traffic areas, TRACON is used to monitor aircraft position via radar. Radar systems provide vital information used in collision avoidance systems and allow proper control and positioning of approaching aircraft.

(a) **TRACON Facility**. A typical TRACON facility is located in the base of the tower cab. It could, however, be located in a separate building near the airport. The TRACON facility is connected to the tower cab by means of an interphone/intercom system, or an interfacility switching system. Besides having the normal transmit and receive equipment access similar to the tower cab, the TRACON facility is provided with the Automated Radar Terminal System (ARTS) equipment access.

(b) **TRACON Equipment Room**. The TRACON equipment rooms normally contain the audio jack panel, patch panel (resectoring panel), power supplies, Navigational Aids (NAVAIDS) monitor and visual aids monitor equipment, Bright Radar Indicator Terminal Equipment (BRITE) and Digital BRITE (DBRITE), collocated Remote Transmitter/Receiver (RTR) equipment and other equipment systems (Air Surveillance Radar, Integrated Communications Switching System associated equipment).

(3) **Flight Service Stations**. Flight service information is provided by FSS and AFSS facilities. These stations provide flight plan and weather service information and information on terminal activity, arrivals and departures, connecting flights, fueling,

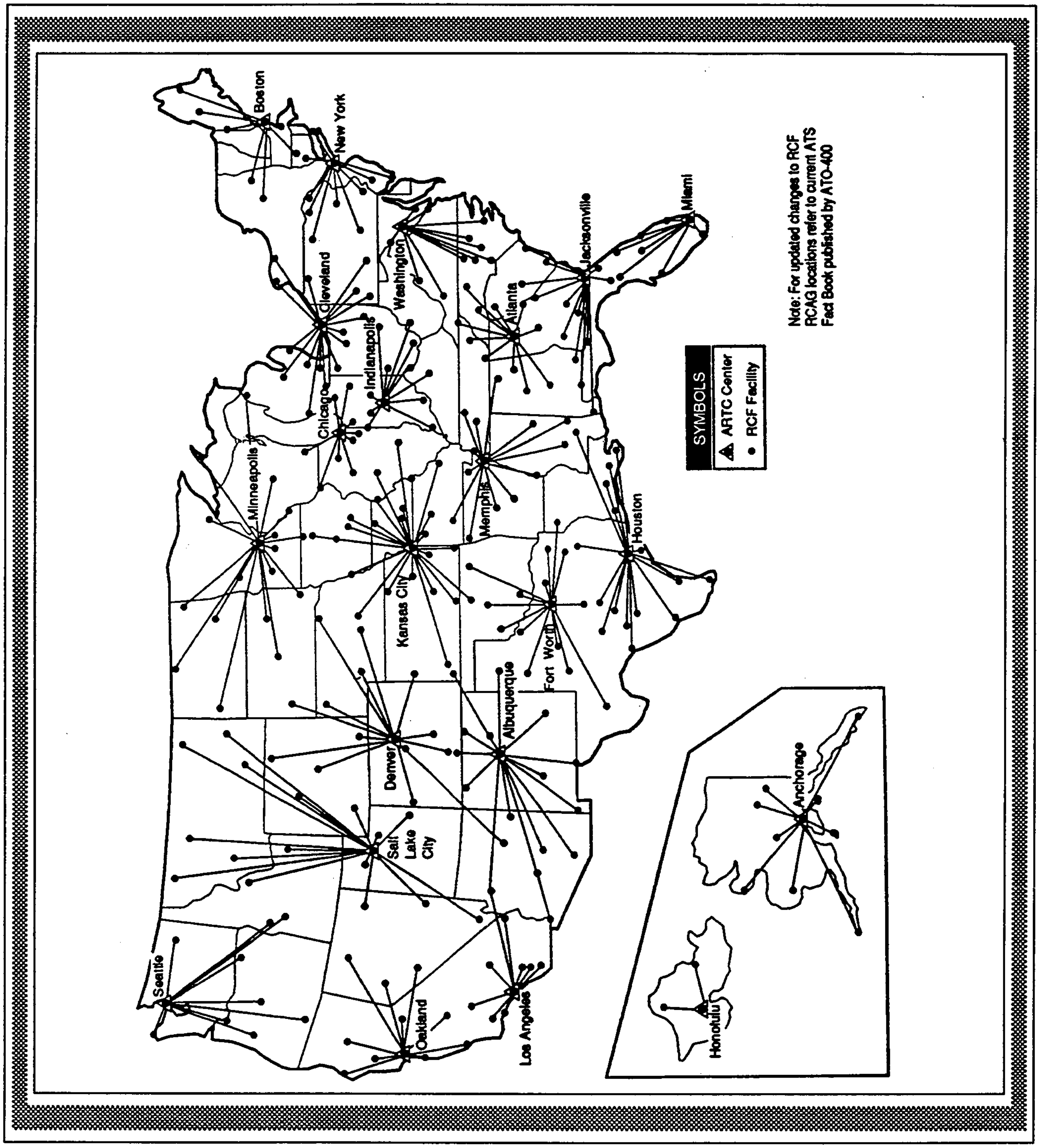
maintenance requests, and other data the pilot may require regarding aircraft servicing and passenger needs. These facilities provide flight service information to pilots via radio and/or commercial telephone communications. AFSS/FSS facilities can provide limited airport information service where there is no control tower. Depending on the size of the AFSS/FSS and its location, the AFSS/FSS radio equipment may be at a collocated Remote Communications Outlet (RCO) or a stand-alone RCO.

d. __En Route Control Facility__. All aircraft operating under Instrument Flight Rules must maintain contact with an ARTCC and/or the tower en route system on the proper A/G radio communications frequency while en route. This radio contact is made through a RCAG communications facility. The ARTCC is the hub of ATC and the focal point for coordination and A/G radio communications. An ARTCC is interconnected via the interfacility communications network with other elements of other NAS facilities. The en route centers control the operation of an RCAG and Air Route Surveillance Radars (ARSR). The connections between the ARTCC and the national RCAG system are illustrated in Figure 2-3, En Route National RCAG System, Major Facilities. Since the RCAG may be collocated at a Very High Frequency (VHF) Omni-Range/VHF Omni-Range Tactical Air Navigation (VORTAC) facility, or another FAA facility several hundred miles from its ARTCC, it is generally connected to the ARTCC by leased landlines or an FAA owned Remote Communications Link (RCL)(i.e., microwave).

(1) __ARTCC Controlled U.S. Airspace__. U.S. airspace controlled by the ARTCC is divided into individual boundary areas. The boundary area of an ARTCC is divided horizontally and vertically into sectors. Each sector is assigned to an air traffic controller who is responsible for control of air traffic within that sector. The air space described by this boundary is defined as the radio coverage area that exhibits no less than -87dBm (10uV) signal strength. This area must also meet the 14dB protection criteria at the aircraft receiver input. A network of long-range radar and beacon equipment provides each controller with data for locating and tracking commercial, general aviation, and military aircraft. An A/G radio communications system enables the controller to communicate with the aircraft.

(2) __ARTCC A/G Radio Communications System__. The ARTCC A/G radio communications system includes equipment which provides the air traffic controller with a means of controlling the equipment at RCAG facilities. Up to five ATC positions are provided in each sector, with A/G radio communications and telephone communications to perform individual functions. Each controller has access to the communications channel at the RCAG providing A/G radio communications

FIGURE 2-3. EN ROUTE NATIONAL RCAG SYSTEM, MAJOR FACILITIES



coverage in the controller's sector of responsibility. Factors such as changes in service to airports, changes in procedures, changes in system usage, etc., can require resectorization. This procedure is accomplished by a resectoring patch panel that allows A/G radio communications frequencies to be assigned to different controller positions.

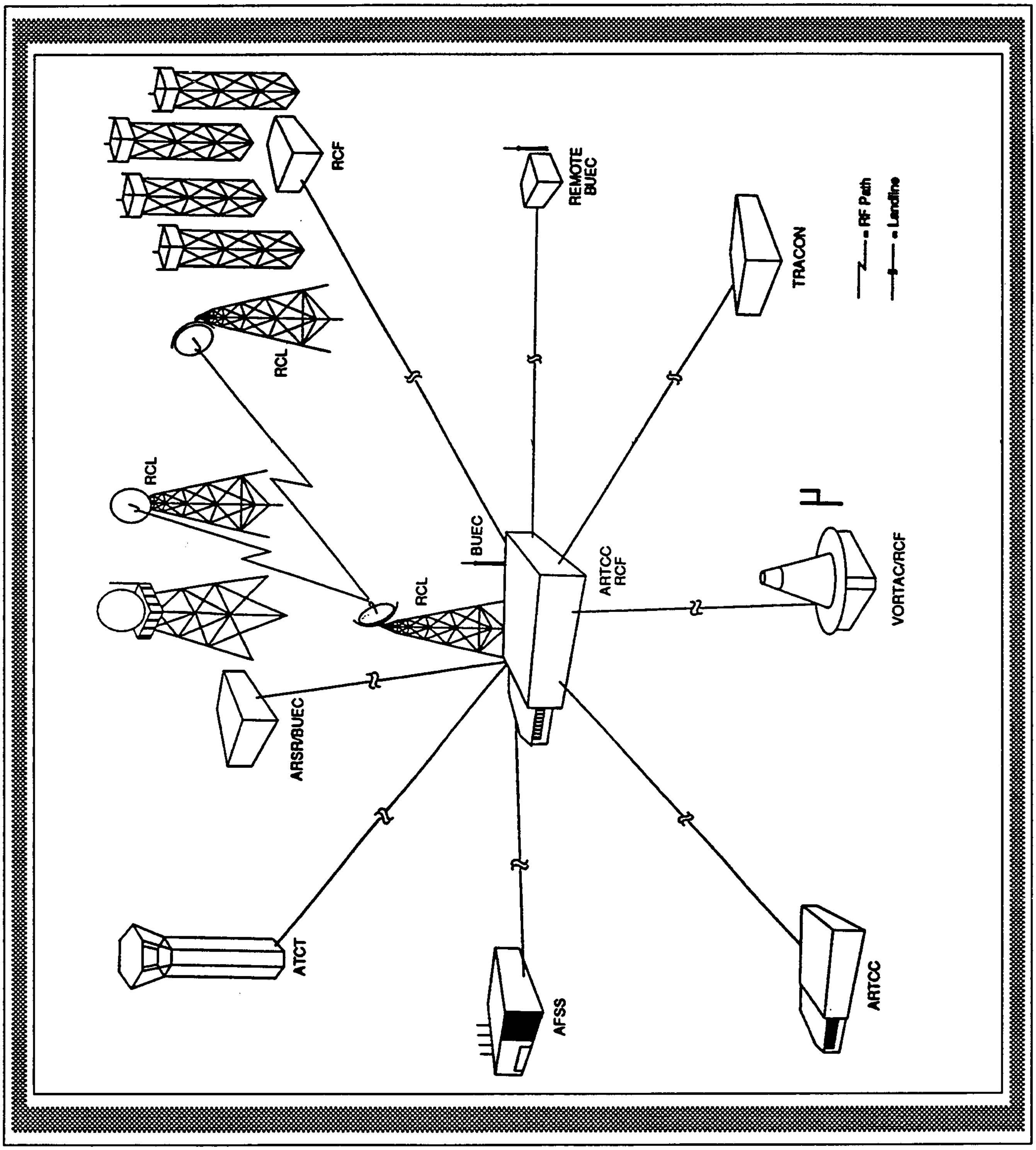
(3) **Air Route Traffic Control Center**. The ARTCC contains equipment used to monitor position and communicate with aircraft en route. As aircraft approach the service area of a TRACON, communications is passed to TRACON and/or ATCT facilities. Figure 2-4, ARTCC and Ancillary Facilities, illustrates these facilities.

(4) **ARTCC Equipment Room**. The ARTCC equipment room is normally located on the lower floor of the ARTCC building and contains the resectoring patch panel, recording equipment, transmit and receive controls, and remote audio equipment. A Backup Emergency Communications (BUEC) processor and patch panel, as well as the BUEC transceivers may be located in the ARTCC equipment room. An RCAG may be collocated with the ARTCC facility.

14. **AUTOMATED TERMINAL INFORMATION SYSTEM**. The Automated Terminal Information System (ATIS) is typically used at high activity airports and is a broadcast only service to pilots. The ATIS supplies information relative to conditions at an airport and is available on a continuous basis, with updates as required, during the operating hours of the airport. The information provided consists of barometric pressure, windspeed and direction, runway in use, airport advisories, etc., and is broadcast either over a VHF Omnidirectional Range (VOR) channel or a dedicated VHF channel. ATIS is available to aircraft at higher activity control towers.

15. **EN ROUTE FLIGHT ADVISORY SYSTEM**. The En Route Flight Advisory System (EFAS) is located at selected FSS's and provides pilots with real-time weather advisories. The weather data provided is obtained from real-time weather observations and pilot reports. When a pilot requests EFAS service, the EFAS specialist monitoring the transmission selects the appropriate ground transmitter and provides the information the pilot requests. When the EFAS station is not manned, an automatic voting system determines the ground receiver location with the best reception from the aircraft and selects the appropriate ground transmitter to relay prerecorded information to the pilot.

FIGURE 2-4. ARTCC AND ANCILLARY FACILITIES



The EFAS will soon be supported by the Automated Surface Observing System (ASOS), the Automated Weather Observing System (AWOS), and in the future by the AWOS Data Acquisition System (ADAS). A high frequency capability is planned to expand the EFAS service to international and trans-oceanic flights.

16. **INTERFACILITY COMMUNICATIONS SYSTEMS**. In the vast majority of cases, cost considerations dictate that FAA owned facilities be used when both FAA owned and leased interfacility communications facilities are available. In exceptional circumstances, the FAA owned facilities may already be fully utilized and additional interfacility communications facilities shall then be obtained on a lease basis.

17-21. **RESERVED**.

SECTION 2. FUNCTIONAL EQUIPMENT DESCRIPTION

22. **GENERAL**. The RCF equipment and its associated antenna system, provide control facilities (ATCT, TRACON, ARTCC, and AFSS/FSS) with radio transmitter and receiver system capabilities. An RCF may be collocated with the control facility or geographically separate from the control facility. The ability to remotely locate an RCF makes it possible to locate antennas to meet air traffic requirements of radio coverage and system protection. A single RCF may serve a number of control facilities. Figure 2-5, RCF and Control Facilities, illustrates the interrelationship between these control facilities.

23. **TRANSMITTER SYSTEM**. The VHF and Ultra High Frequency (UHF) transmitter system associated with A/G radio communications includes RF, antenna, audio, and control equipment. All new RCF transmitter equipment will be solid-state. Vacuum-tube designed tone signaling and control equipment is also being replaced on an emergency case-by-case basis with solid-state control equipment until such time as the equipment from the proposed CIP is deployed.

a. **RF Equipment**. The RF equipment is comprised of main and standby transmitters, and the associated transmission system. The antenna system consists of the antennas and transmission lines which connect the antennas to the transmitters, combiners, coaxial line, coaxial RF line sections, circulators, filters, and coaxial relays. The relays transfer main and standby transmitter outputs to the antenna system. The main and standby equipment provide required redundancy and are used interchangeably. The standby equipment is not considered a backup system. There may be tunable BUEC transceivers and their associated antenna systems at alternate locations.

b. **Control and Audio Circuits.** The control and audio circuits between the control facility and the RCF are FAA owned landlines, RCL's or leased unconditioned voice grade landlines. Transmit audio from the control facility and receive audio from the RCF pass over these circuits. Some sites have SS-1/SS-4 alternate leased line switching. A leased line is capable of being switched when the primary line fails.

c. **Antennas**. The transmit antennas may be omnidirectional or directional depending on the coverage requirements. The antenna could have a gain of 0dB or more. However, the license for the frequency must state the antenna type, directivity, and gain.

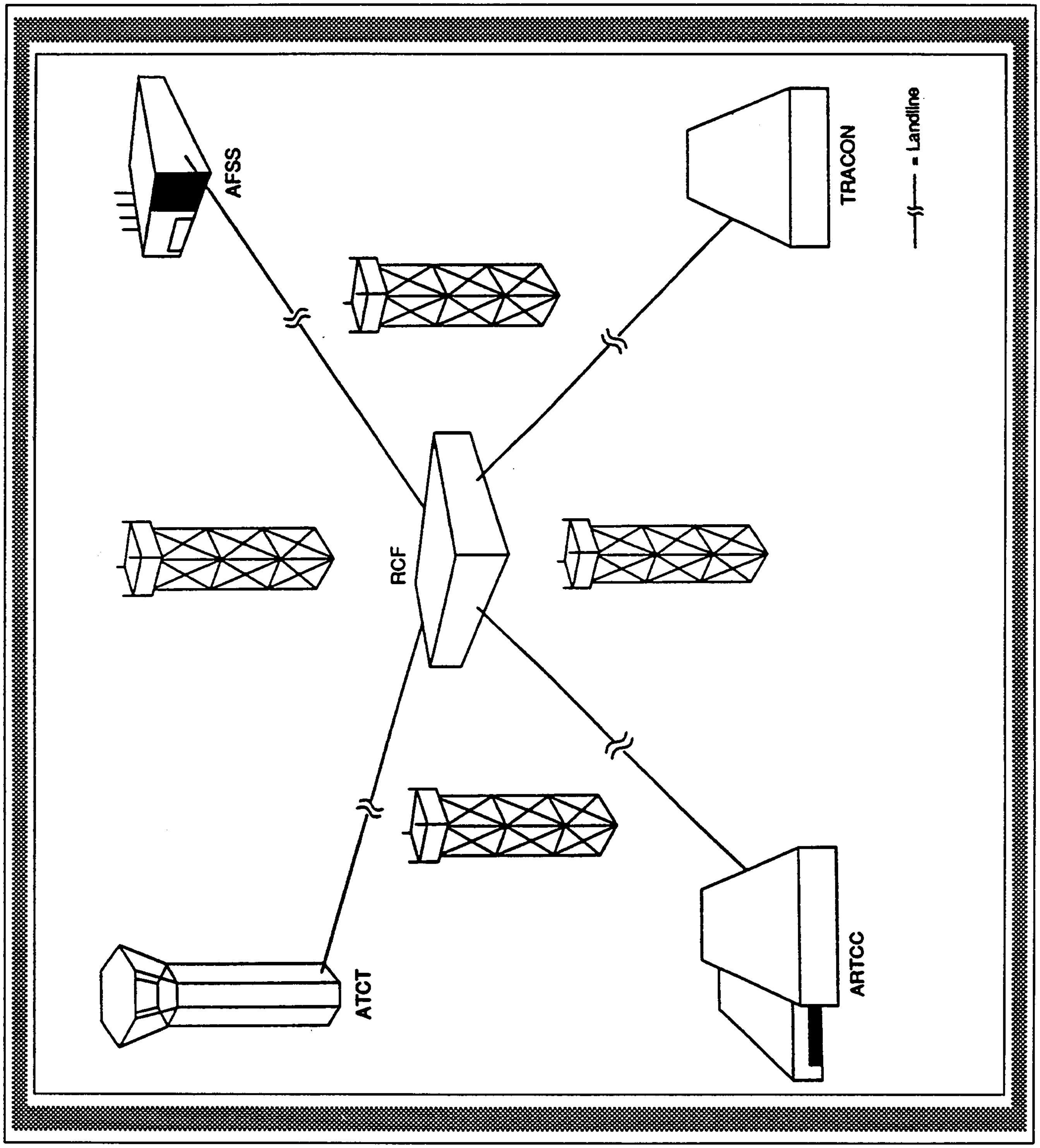
d. **Operation**. The VHF and UHF bands are presently used by the FAA for two-way communications in the ATC service. The existing crystal-controlled, fixed-frequency, VHF exciters have a power output of 10 watts in the 118 MegaHertz (MHz) to 137 MHz band. The UHF exciters have a power output of 10 watts in the 255 MHz to 400 MHz band. These exciters, when required, use a Linear Power Amplifier (LPA) to increase output power to 50 watts to provide increased service volume coverage. Additionally, BUEC transceivers are functional in either the VHF or UHF bands and when required (ARTCC only) have an RF power output of 20 watts.

24. **RECEIVER SYSTEM**. The VHF and UHF receiver systems associated with A/G radio communications include: RF, antenna, audio, and control equipment. Vacuum-tube designed tone signaling and control equipment is being replaced on an emergency case-by-case basis with solid-state control equipment until such time that newer equipment is deployed.

a. **RF Equipment**. The RF equipment is comprised of main and standby receivers and the associated antenna system. The antenna system consists of the antennas, transmission lines that connect the antenna to the receivers, multicouplers, filters, and coaxial relays. The coaxial relays are used to transfer main and standby receiver RF inputs to the antenna systems. There may be tunable backup transceivers and associated antenna systems at alternate locations.

b. **Control and Audio Circuits**. The control and audio circuits between the control facility and the RCF are FAA owned landlines, remote communications links, or leased unconditioned voice grade landlines. Transmit audio from the control facility and receive audio from the RCF pass over these circuits.

FIGURE 2-5. RCF AND CONTROL FACILITIES



c. **Antennas**. The receive antennas may be omnidirectional or directional depending on the coverage requirements. The antenna could have a gain of 0dB or more. However, the license for the frequency must state the antenna type, directivity, and gain.

25. **ANTENNA SYSTEM**. Half-wave, vertically polarized, omnidirectional dipole antennas enclosed in fiberglass radomes are used. The dipoles have an area of non-coverage directly over the antenna. This non-coverage area leads to the requirement, in high and super high sectors, for the RCAG site be located outside the sector boundaries and not along an air route. Cross-channel interference, transmitter power reductions, an increase in A/G radio communications, and requirements for additional frequency channels demand better antennas. The configurations are single VHF and UHF, and stacked collinear VHF and UHF arrays. Directional VHF and UHF antennas are also used to satisfy special coverage applications.

26. **REMOTE MAINTENANCE MONITORING**. The Remote Maintenance Monitoring (RMM) system will improve the day-to-day operations and reduce maintenance costs. The equipment goal is to provide an efficient system approach to integrate the requirements of the Environmental Remote Monitoring Subsystem (ERMS) sensoring and maintenance monitoring, and emergency backup battery power control. A single maintenance monitoring equipment set is used to allow the monitor equipment to integrate the monitoring facility with all of its associated remote facilities. The remote site and facility maintenance panels have the ability to interface with the Maintenance Data Terminal (MDT). Maintenance monitoring parameters and Site Adaptation Data (SAD) tables will be reviewed and/or edited locally with a MDT, or the Maintenance Terminal (MT). The monitoring equipment is to provide ATC facilities with a standardized remote monitoring system that incorporates expansion and reconfiguration capabilities. The modular construction of monitoring equipment accommodates the FAA size requirements for ARTCC's, ATCT's, TRACON's and ATC facilities and their associated remote radio facilities.

a. **Monitor Equipment Functions**. Automatic detection and alarm sensors provide fault information for failures occurring within the indicator, display, and control subsystems and for failures occurring within main, standby, or backup equipment. An alarm is sensed by the closure of a normally open dry relay contact. This alarm information is then converted to a serial digital format and transmitted over the four-wire voice grade landline. Digital will be according to manufacturer's specifications. The alarm system shall be capable of displaying a momentary as well as a constant alarm condition.

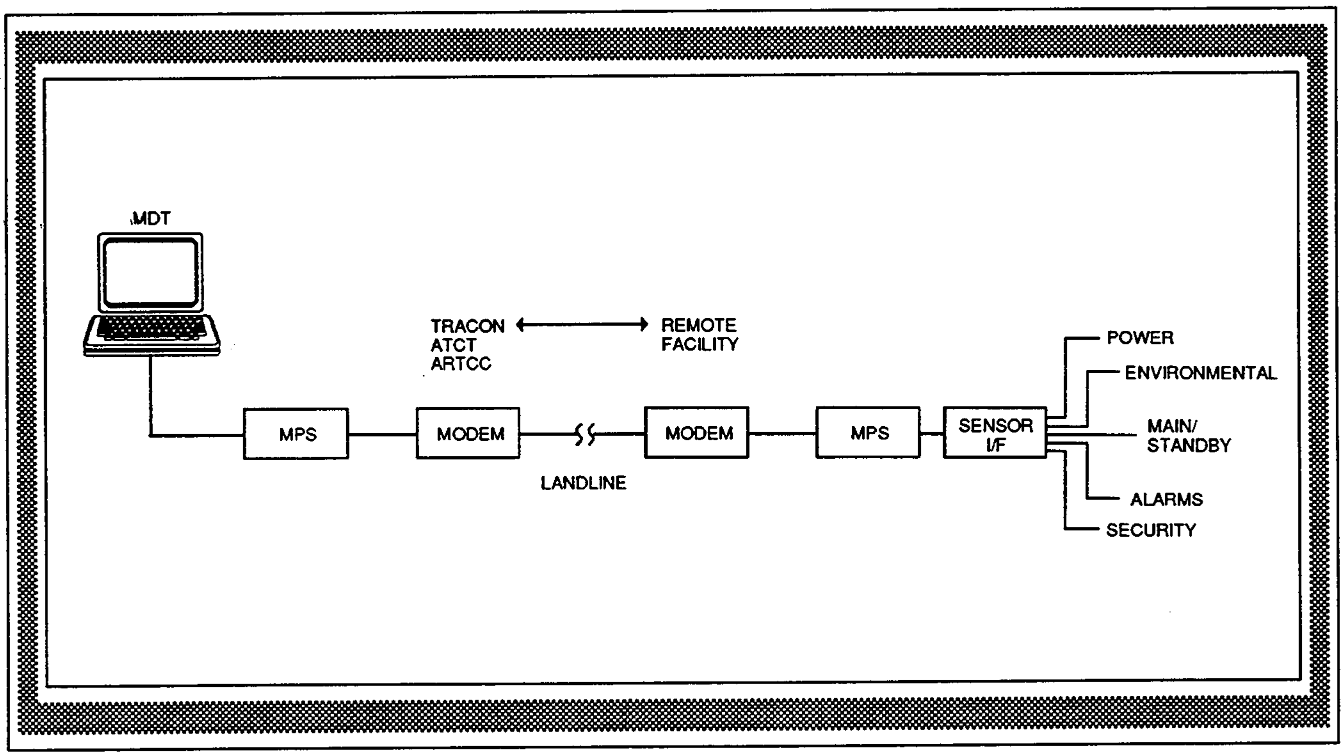
b. <u>Remote Maintenance Monitoring</u>. Facility RMM will be provided through the monitoring equipment. The equipment will provide each RCF with performance monitoring, and status certification capability which can be accomplished from centralized control and work centers. The RCF systems have a standardized subsystem for remote monitoring of the operational status and key performance parameters of A/G radio communications equipment, selected environmental building parameters (ERMS), standby power source status, and site security over the same voice grade line as the analog voice communications. ARTCC's are considered the primary monitoring sites; however, other sites such as ATCT and FSS/AFSS facilities equipped with RMM consoles and interface components may also monitor communications equipment status. A diagram of RMM is shown in Figure 2-6, Remote Maintenance Monitoring System.

27. **EMERGENCY COMMUNICATIONS**. Some FAA facilities maintain emergency communications A/G radio equipment to satisfy their particular requirements.

a. <u>Terminal Facility Emergency Transceiver</u>. Portable self-contained multi-frequency transceivers are located at ATCT and TRACON facilities to provide emergency A/G radio communications in the event of an airport emergency or primary power failure. These transceivers ensure that a source of A/G radio communications is always available and used only in the event of catastrophic failures of the main and standby transmitter/receiver systems. Use is restricted to emergencies because of the limited number of frequencies, low power output, and potential for producing RF interference. Order 6510.4A, Radio Communications Requirements for Air Traffic Control Facilities, addresses current applications for emergency transceivers.

b. <u>En Route Facility Backup Emergency Communications</u>. Fixed remote tunable VHF and UHF transceivers are used to provide backup emergency A/G radio communications for ARTCC's located throughout the United States. In the past, BUEC equipment was installed at various alternate sites, i.e., ARSR, VOR, and RCL sites. The CIP made provisions for locating BUEC installations for optimum coverage of the required airspace. However, BUEC equipment shall not be located at the RCF site due to the tuning capability of the transceiver and the potential for causing cross-channel, intermodulation, and harmonic interference. BUEC tunable transceivers are controlled at the ARTCC through the BUEC processor, control group equipment, and BUEC selector units at the controller's position. The BUEC processor provides automatic allocation of transceivers with a predetermined priority for up to 120 controller positions. The system capability has been or will be expanded from up to 60 VHF and 60 UHF frequencies to up to 120 VHF and 120 UHF frequencies.

FIGURE 2-6. REMOTE MAINTENANCE MONITORING SYSTEM

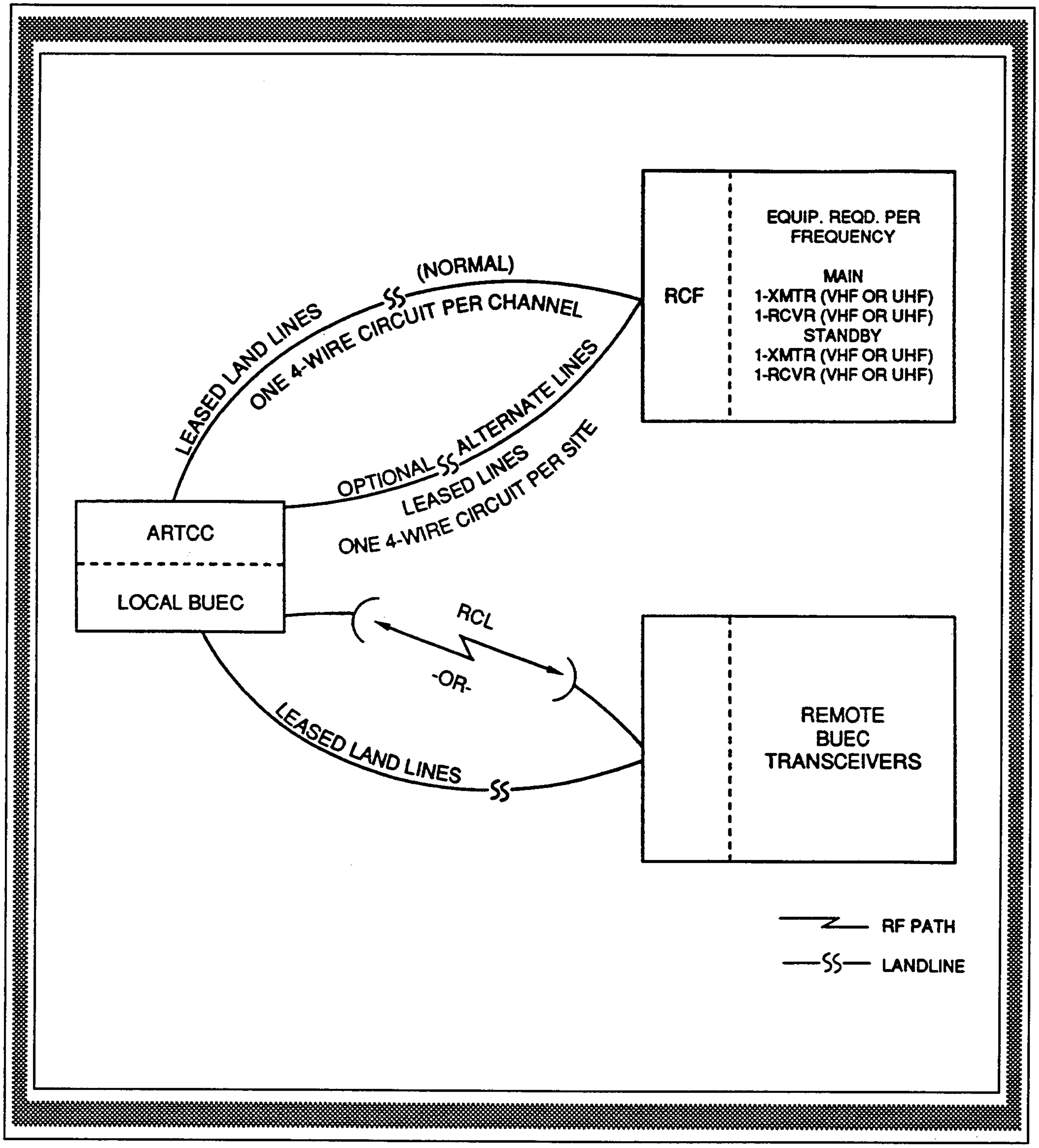


The BUEC priority module can select up to 10 remote locations with the original system, and up to 8 remote locations with the new modules. Normally, only four remote sites are required to cover the actual airspace of a particular frequency. Figure 2-7, ARTCC A/G Communications System Redundancy, illustrates the system redundancy.

28. **SUSTAINING BUEC SYSTEM**. The present BUEC system is provided by controllable multichannel equipment located within ARTCC facilities and some remote collocated facilities, i.e., ARSR and TRACON sites. The sustaining BUEC system has the principal function per Order 6510.4A to provide primary frequency backup to individual sector communications when an RCF frequency is out-of-service. Sustaining BUEC will use single frequency equipment installed at remote sites within weather proof enclosures. Refer to chapter 6 paragraph 200, for more information.

29.-32. **RESERVED**.

FIGURE 2-7. ARTCC A/G COMMUNICATIONS SYSTEM REDUNDANCY



SECTION 3. EQUIPMENT DESCRIPTION

33. **GENERAL**. The following equipment is typically located at A/G radio communications facilities.

a. Antennas.

b. Standard 83-inch high racks (EIA 19" W).

c. RF line section panel/RF relay patch panel.

d. VHF transmitters.

e. VHF receivers.

f. UHF transmitters.

g. UHF receivers.

h. VHF transceivers.

i. UHF transceivers.

j. Remote control and monitoring equipment.

k. Lightning and surge protection.

n Battery supply with charger.

n DC/AC TELCO Invertor.

n Mini-Demarc. n Equipment may not be in place.

The RCF may include additional equipment such as filters, combiners, and multicouplers as required to meet the objectives of CIP Project 24-02, Communications Facility Consolidation Network. The quantity and types of radio equipment required by the various control facility categories are given in Table 2-1, Radio Equipment. For updated radio equipment requirements, refer to Order 6510.4A and recommendations made by CIP Project 44-03, Radio Frequency Interference (RFI) Elimination Project.

34. **VHF Transmitters**. The VHF A/G transmitter consists of an exciter and optional LPA. The exciter is normally used independently and is capable of providing a carrier output power of 10 watts. The exciter supports 25 KiloHertz (kHz) channel spacing between 117.975 MHz and 136.975 MHz.

TABLE 2-1. RADIO EQUIPMENT

TYPICAL QUANTITIES OF EQUIPMENT PER CONTROL FACILITY

CATEGORY OF CONTROL FACILITY POSITIONS	RADIO OPERATING	VHF FREQUENCIES	UHF FREQUENCIES	MAIN AND STANDBY EQUIPMENT	EMERGENCY TRANSCEIVER
Non-approach Control Tower (Low Activity, Visual Flight Rules: Operates only 16 Hrs daily)	2 2	3 Transmit 3 Receive	If Military 2 Transmit 2 Receive	VHF = 6 Transmitter 6 Receivers UHF (If assigned) 4 Transmitters 4 Receivers	1 VHF, 1 UHF (If required)
Non-radar Approach Control Tower (Medium activity)	3	4 Transmit 4 Receive	If Military 3 to 4	VHF = 8 Transmitters 8 Receivers UHF (If assigned) 6 to 8 Transmitters 6 to 8 Receivers	2 VHF, 1 UHF (If assigned)
Radar Approach Control Tower (High activity)	(Tracon) 4 to 20 as required	7 to 24 Transmit 7 to 24 Receive	4 to 10 Transmit 4 to 10 Receive	VHF = 14 to 48 Transmitters 14 to 48 Receivers UHF = 8 to 20 Transmitters 8 to 20 Receivers	2 VHF, 1 UHF 14 to 48 (TRACON) 1 VHF, 1 UHF (Tower Cab)

The LPA is capable of providing a power output of 50 watts when driven by the exciter. The use of the 50 watt LPA is justified when the power output of 10 watts from the exciter is not sufficient to provide a -87 decibel relative to 1 microvolt (dBm) signal level at the input of the aircraft receiver located at the edge of the associated service volume. The VHF A/G transmitter has a failsafe mode which, after sensing power amplifier failure, switches the output of the exciter directly to the antenna system.

35. **UHF TRANSMITTERS**. The UHF A/G transmitter is similar to the VHF exciter and optional LPA except for operating frequencies. UHF transmission is between 225.000 MHz and 399.975 MHz with 25 kHz channel spacing.

36. **VHF RECEIVERS**. The VHF A/G receiver associated with ATC service is capable of reception on any one of 760 frequencies spaced 25 kHz apart between 117.975 MHz and 136.975 MHz.

37. **UHF RECEIVERS**. The UHF receiver associated with ATC service A/G radio communications is similar to the VHF receiver in overall design, except for its operating frequency and number of frequencies available. The UHF receiver is capable of reception on any one of 7,000 channels spaced 25 kHz apart between 225.000 MHz and 399.975 MHz.

38. **NEW TRANSMITTERS AND RECEIVERS**. During the revision of this order new activity has started to purchase new VHF and UHF transmitters and new VHF and UHF receivers. This equipment could be used in new or collocation projects. The new equipment as described in the procurement specification will fit electrically and physically into current RCF equipment racks and facilities without alteration. One characteristic although is different in the VHF and UHF transmitters. These units are not to be used with LPA's that require control (i.e., PTT or activate) leads between the transmitter and the LPA. No leads are provided in the new equipment. Refer to appendix 3 for equipment specifications.

39. **REMOTE CONTROL SYSTEM**. The remote control system at the RCF sites includes equipment to interface incoming audio landlines with equipment to be controlled from a remote facility.

a. **Components**. New installations shall use solid-state radio control equipment at control facilities for selection of A/G transmit or receive radio channels and transmitter keying. Remote operation includes paired transmitter/receiver control systems. The basic components of each system include an active jack unit, an audio unit, one or more selector units, a power supply assembly, and a patch panel.

b. **Control Equipment**. Various types of radio control or Voice Frequency Control System (VFCS) interface equipments are utilized for remote control of NAS transmitters and receivers. One of the more popular systems in use today is the LCT-CNTR-IA and RCT-RCAG-IA (VODATA) system. Speech is contained in the 300 to 3000 Hertz (Hz) range. Control functions are transmitted using the Frequency Shift Keying (FSK) method at 2880 Hz ±60 Hz. A notch filter is used to remove the 2880 Hz signaling tone. This equipment is completely solid-state and contains all of the equipment needed for processing audio and control signals for transmit and receive, keying, muting, and main/standby selection functions. Control of an RCF frequency requires a four-wire voice grade, unconditioned landline or RCL.

c. **Functions**. Keying, muting, and transmitter/receiver frequency selection functions are represented as a 12-bit synchronous data word transmitted at 150 bits per second. The data word is superimposed on the voice signal at the origination site interface, and the combined signal is transmitted to the RCF. The voice and data are received at the RCF site, where it is separated by a similar interface and delivered to the radio equipment.

40. **ANTENNAS**. A number of antenna configuration and antenna arrays are in use at RCF facilities.

a. **Configurations**. The antenna configurations are in single and dual stacked collinear arrays. All are designed to match a 50 ohm characteristic impedance transmission line. Each dipole within a stacked array is independently operated with a high degree of isolation. The electrical, mechanical, and installation characteristics are compatible with existing and future FAA facility applications.

b. **Antenna Arrays**. Highly directional antennas are also utilized for resolving coverage difficulties. A directional collinear antenna is available that has approximately four dBi gain (directivity). Another directional Yagi-type antenna is also available which provides approximately 10 dBi gain.

41. **MULTICOUPLERS**. Active receiver multicouplers which provide 0 dB through-loss shall be used when an RCF uses multiple receivers and site analysis dictates that more than one receiver would be connected to a single antenna. The unit may have an output capacity of 16 ports; however, current policy stipulates that only four are used. This criteria is predicated on single point failure potential of a system architecture based on more than four receivers connected through one multicoupler and one antenna. Unused ports shall be terminated with 50 ohm loads. The multicoupler operates in the 118 MHz to 138 MHz range for VHF and 225 MHz to 400 MHz range for UHF.

42. **COAXIAL RF LINE SECTIONS**. The coaxial RF line sections are self-contained, passive devices configured for permanent mounting in a 50 ohm RF line. They are used to monitor the Voltage Standing Wave Ratio (VSWR) of transmission systems. Coaxial RF line sections, the correct technical term, are sometimes referred to as an RF body.

43. **COMBINERS**. Transmitter combiners shall be used when site analysis dictates the need to use a single antenna for more than one transmitter. Through-loss is less than 3.0 dB for up to four transmitter/antenna combinations. Consideration shall be made as to the coverage area impact of the combiner through-loss.

44. **ISOLATORS**. Isolators are non-reciprocal devices with three ports and are used for Intermodulation (IM) control. This is accomplished by terminating reflected or other incoming signals into a 50 ohm load on the third port.

45. **FILTERS**. Both transmitters and receivers shall use filters when necessary to prevent transmitter noise and receiver desensitization. All transmitters shall employ harmonic and intermodulation suppression filters to reduce third order harmonics which may be magnified by the use of combining systems.

46. **TRANSMISSION LINE**. Internal RF coaxial cable transmission paths (i.e., to/from an internal RF cable patch panel) or external short jumper cables shall utilize double shielded RG-214 or lower loss RG-331. For long transmission paths (i.e., from facility to antenna tower) the RF coaxial transmission cable shall be the lower loss RG-333. Where RG-214 cable is not suitable (i.e., multicoupler applications) double shielded RG-223 shall be used keeping lengths as short as possible. The RF transmission cable in all applications shall have a nominal 50 ohms impedance. Older cable types that might exist (RG-8, RG-213 and RG-17) shall be replaced with the recommended, lower loss RF cable types.

47. **EQUIPMENT RACKS**. The basic equipment rack frequently used to house electronic equipment has a modular solid-sided steel sheet metal cabinet with rear access door(s). A detailed description and drawings of the 19 inch Electronic Industry Association (EIA) racks are contained in FAA-E-2672A, Rack, Cabinets, Solid-Sided and Open-Sided Types. The following types of equipment cabinet racks are presently available from the FAA Logistics Center:

NSN 5975 01 094 1436-1, Rack, Single Door, 83 inches High

NSN 8200 00 130 4280-1, Rack, DSRCE configured, 83 inches High

48.-51. **RESERVED**.

SECTION 4. SITE CHARACTERISTICS

52. **GENERAL**. A majority of RCF site structures are over 40 years old. Heating, ventilation, and air conditioning are insufficient, in many cases, for the equipment housed in the structures. Much of the RCF equipment located at some sites was designed in the mid 1950's and uses vacuum-tube and electromechanical relay technology. Many remote sites have already changed over to solid-state remote control equipment.

53. **STAND-ALONE RCF**. An FAA study completed in April 1984 concluded that 12 VHF and 12 UHF channels can be consolidated at a single RCF through the use of external isolation devices such as combiners and multicouplers. RCF antenna site configurations and RFI suppression devices should be considered. As a result, the present configurations may be changed. RCF antennas are typically mounted on steel towers with hexagonal or rectangular platforms with sidearms for antenna separation. A site layout for an RCF is shown in Figure 2-8, Stand-Alone RCF Site Layout.

54. **COLLOCATED RCF**. The FAA, in a project called "Cosite", investigated the effects of antennas on RCF coverage when collocated with a VORTAC site. The EMC and antenna configuration guidelines for use in the RCF should also be considered. These sites require pole mounting of RCF antennas. Typical antenna mounting details are shown in Figure 2-9, Typical Antenna Pole Mounting. An integral RCF collocated with a VORTAC is shown in Figure 2-10, Typical Integral RCF/VORTAC Antenna Mounting. The antenna poles selected for use at collocated RCF NAVAIDS are fiberglass or wood. Another configuration is illustrated in chapter 6, Figure 6-38, Typical Region Supplied Let-Down Pole Antenna. These poles exhibit a high dielectric constant as compared with metal poles. The RCF antennas are typically mounted on the cross-arm in let-down pole applications. The antenna pole platform and the antenna pole cross-arm shall be oriented on the long axis with respect to the VORTAC facility. RCF transmission lines may be run underground (the recommended method) or suspended between the building and antenna pole via messenger cable.

55. **BUILDING FLOOR PLANS**. The impact of the building floor plan space for the added equipment shall be determined since sufficient space may not exist to meet standard space requirements for access to the front, side and rear of the equipment. The actual RCF building dimensions should be based on the quantity of equipment reguired to support the number of frequencies to be installed at the collocated RCL/RCF facility.

FIGURE 2-8. STAND-ALONE RCF SITE LAYOUT

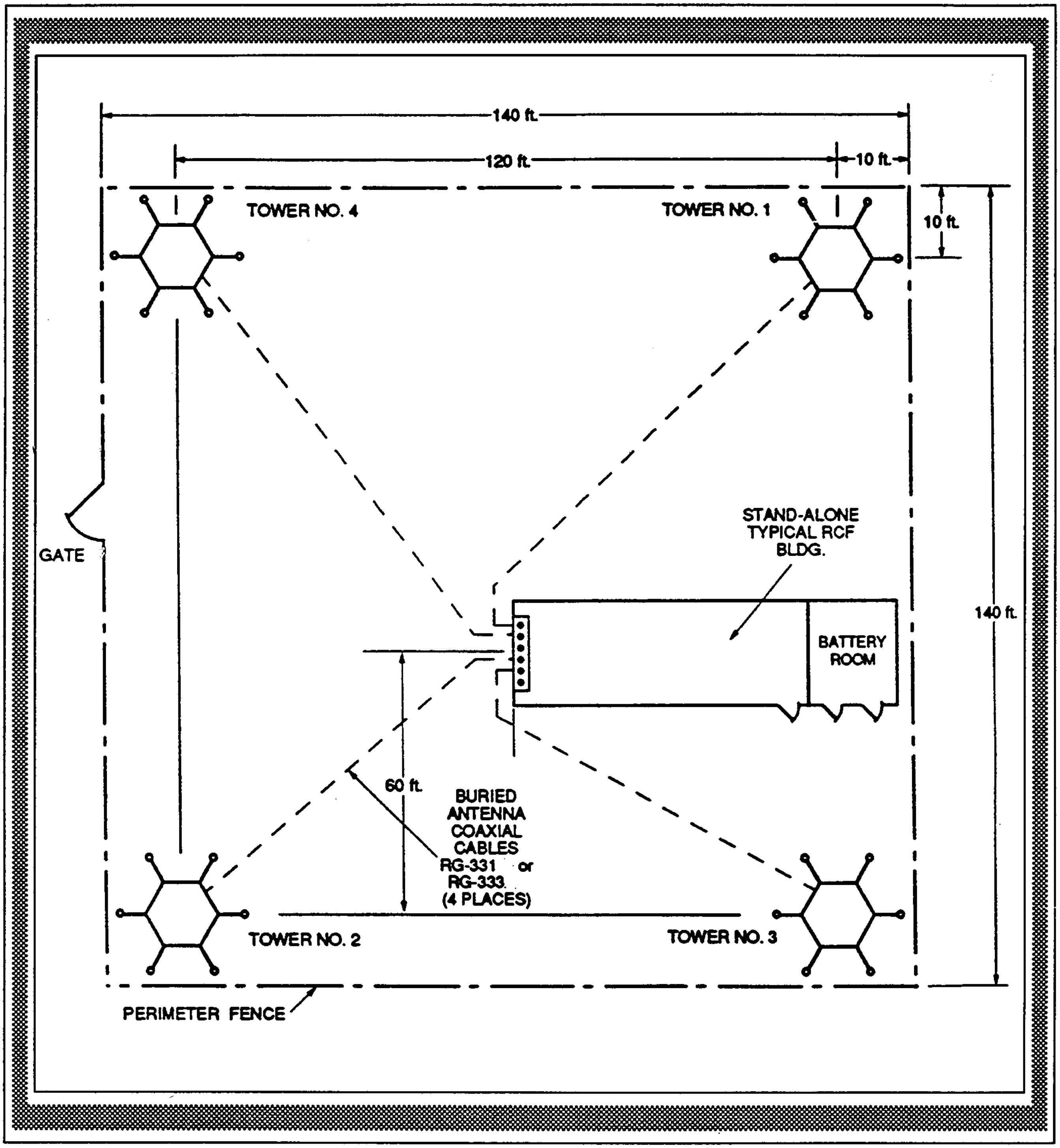


FIGURE 2-9. TYPICAL ANTENNA POLE MOUNTING

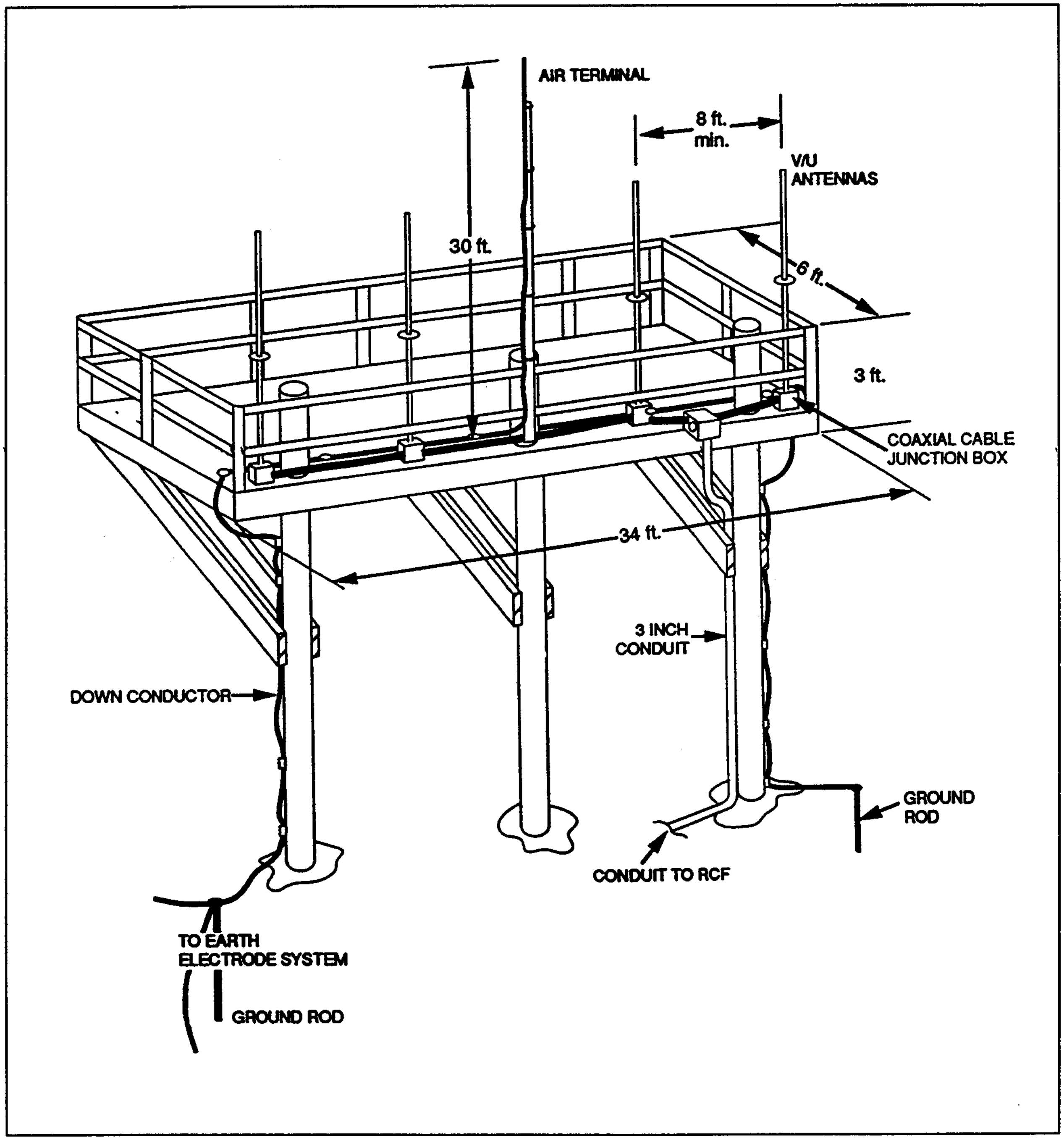


FIGURE 2-10. TYPICAL INTEGRAL RCF/VORTAC ANTENNA MOUNTING

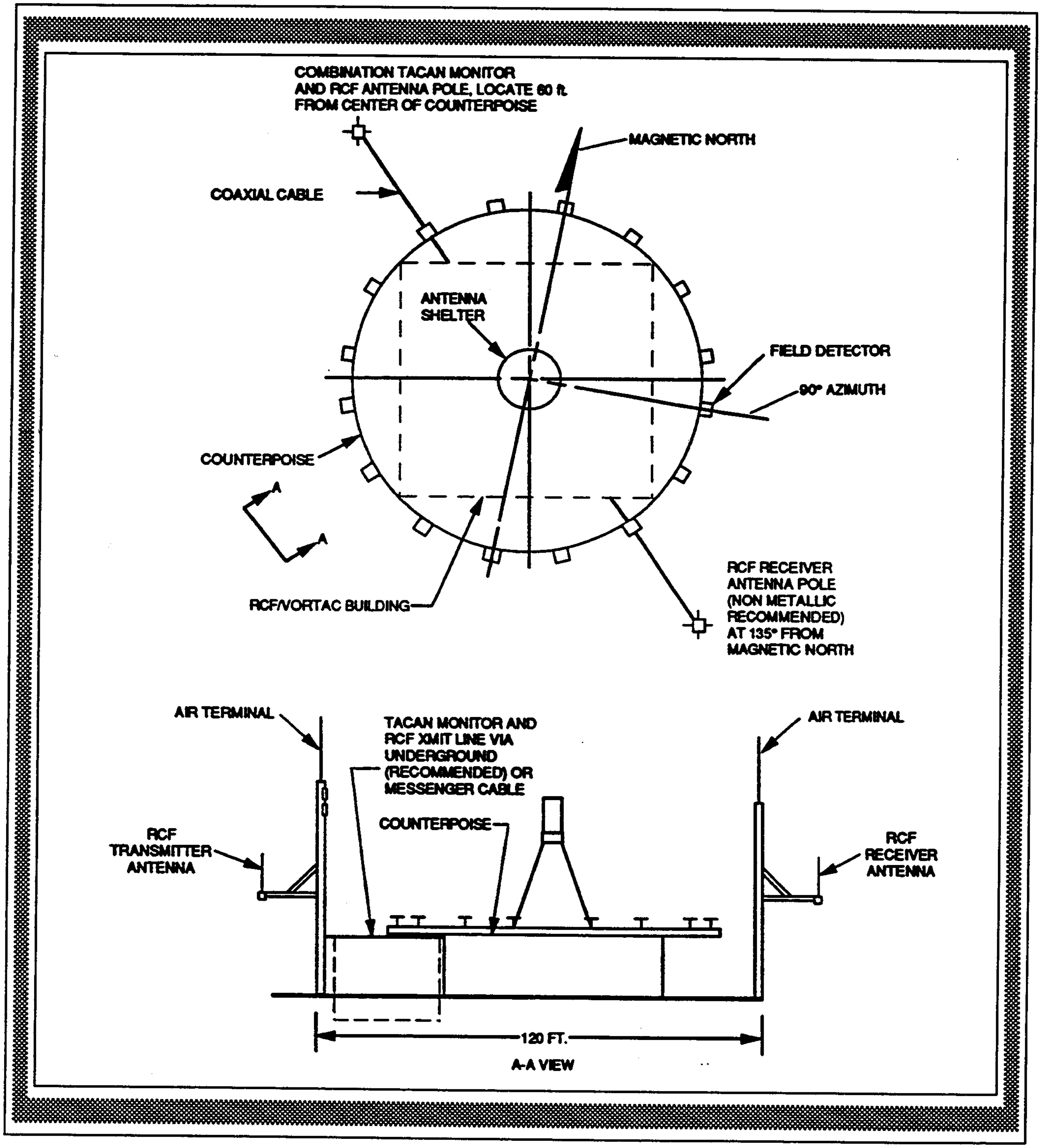


FIGURE 2-11. TYPICAL RCF FLOOR PLAN WITH RACKS (NO ENGINE GENERATOR)

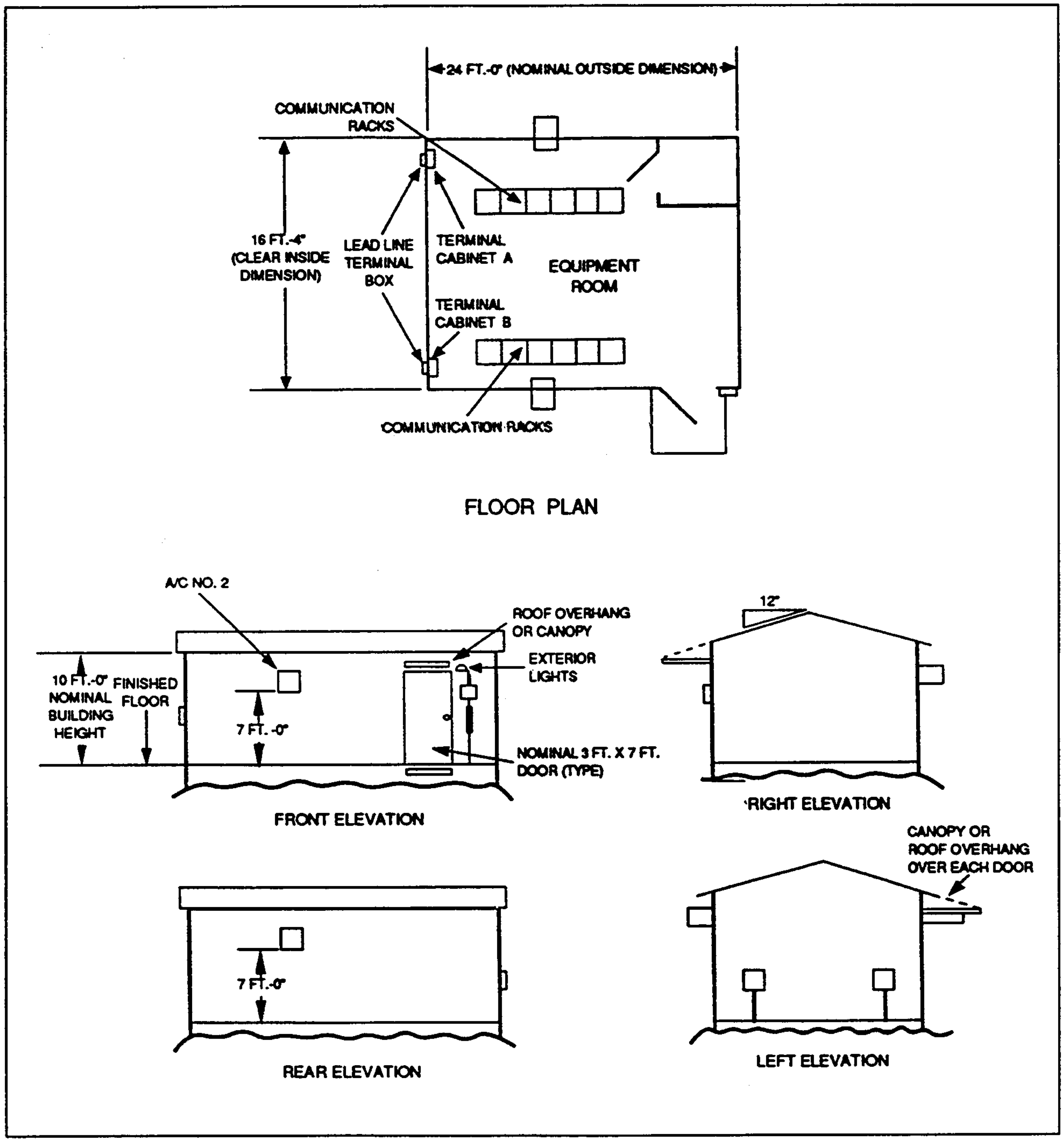


FIGURE 2-12. TYPICAL RCF/RCAG FLOOR PLAN WITH RACKS

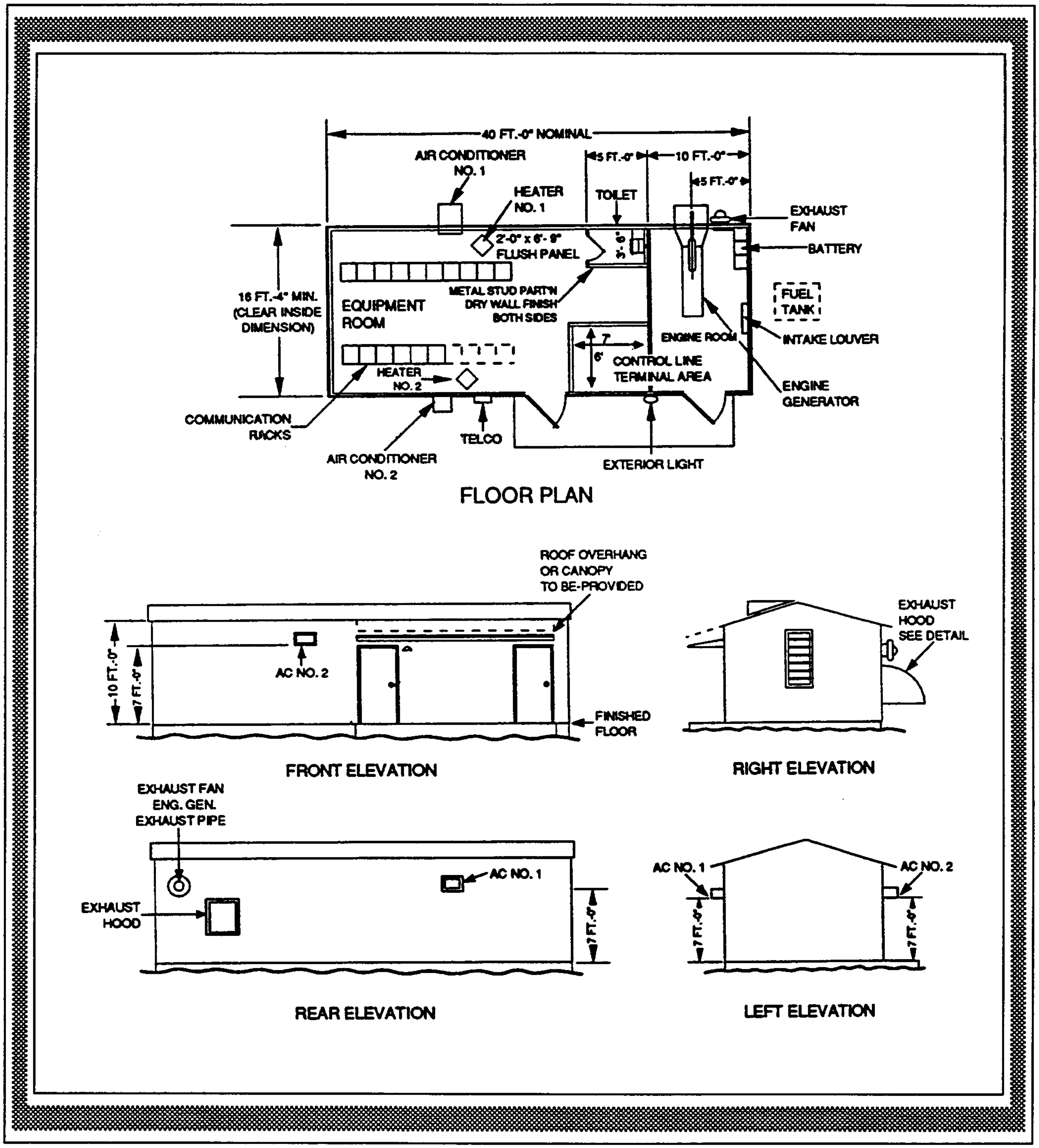
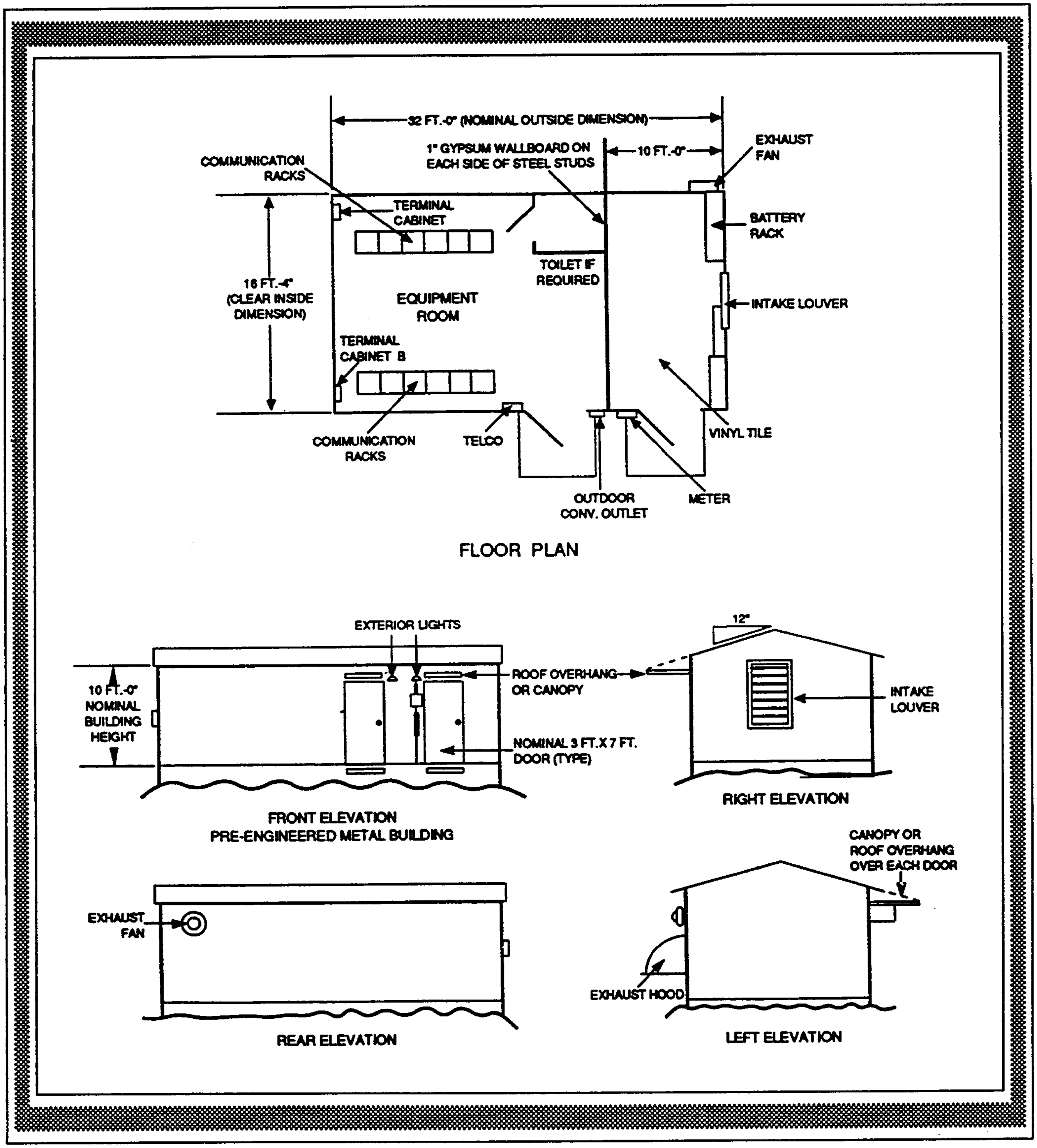


FIGURE 2-13. TYPICAL RCF/RTR FLOOR PLAN WITH RACKS



a. **Racks and Equipment**. Typical rack and equipment floor plans for stand-alone RCF/RCAG/RTR are shown in Figure 2-11, Typical RCF Floor Plan with Racks (No Engine Generator), Figure 2-12, Typical RCF/RCAG Floor Plan with Racks, and Figure 2-13, Typical RCF/RTR Floor Plan with Racks.

b. **Collocated Equipment**. Typical RCF/VORTAC collocated equipment floor plans are shown in figures 2-14 through 2-18 listed in subparagraphs (1)-(6). These figures illustrate the equipment floor plan layout showing equipment, RCF/VORTAC building conduit, and junction boxes. The communications equipment backup power battery racks are mounted no closer than three feet from the NAVAIDS battery rack. Telephone Company (TELCO) termination equipment installation shall be enclosed in a chainlink barrier isolated from FAA equipment where possible. This would allow TELCO access to their equipment yet maintain security of the FAA equipment.

(1) Figure 2-14, RCF/VORTAC Collocated in a 21' Diameter Building, shows the floor plan and six communications equipment racks and five future equipment racks collocated in the 21-foot size RCF/VORTAC building that is not equipped with an engine generator.

(2) Figure 2-15, RCF/VORTAC Collocated in a 20'x 36' Building, shows four communications equipment racks collocated in the RCF/VORTAC facility.

(3) Figure 2-16, RCF/VORTAC Collocated in a 25'x 31' Building, shows four communications equipment racks collocated in the RCF/VORTAC facility. Although only four racks are shown for EFAS or ATIS equipment, there is sufficient room for several more communications equipment racks.

(4) Figure 2-17, RCF/VORTAC Collocated in a 32' Diameter Building, shows four communications equipment racks collocated in the building floor plan.

(5) Figure 2-18, RCF/VORTAC Collocated in a 36'x 36' Building, shows five communications equipment racks collocated in the building floor plan.

(6) An FAA-sponsored study has been conducted to analyze concepts for a future standard shelter for RCF/VORTAC equipment. One of these concepts is a 32-foot diameter signal counterpoise erected over a 21-foot square facility shelter. The floor plan for this building is shown in Figure 2-19, Future RCF/VORTAC Facility.

c. **RCF Collocated at RCL**. The following are illustrations of RCF/RCL collocated equipment building floor plans.

FIGURE 2-14. RCF/VORTAC COLLOCATED IN A 21' DIAMETER BUILDING

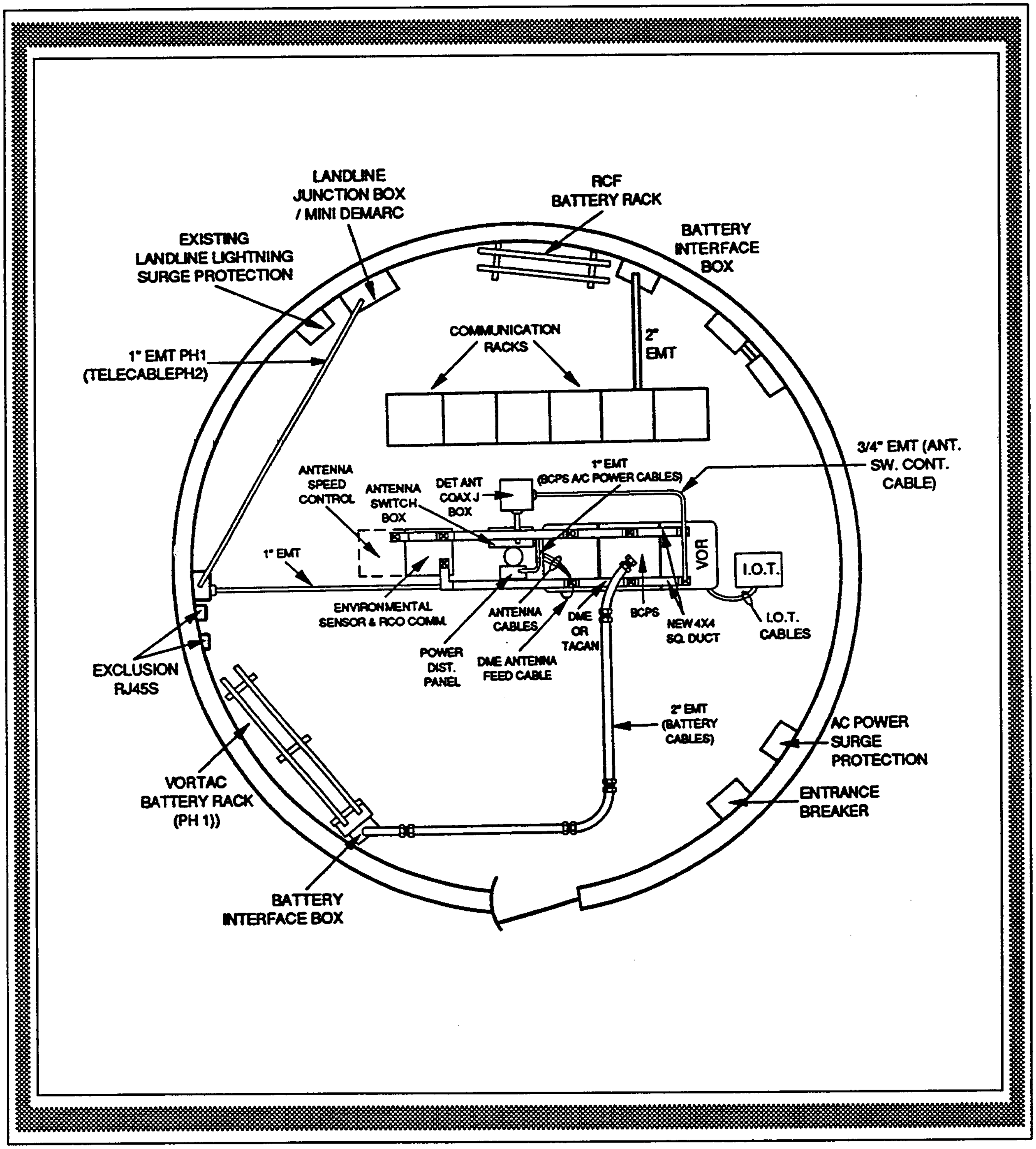


FIGURE 2-15. RCF/VORTAC COLLOCATED IN A 20'x 36' BUILDING

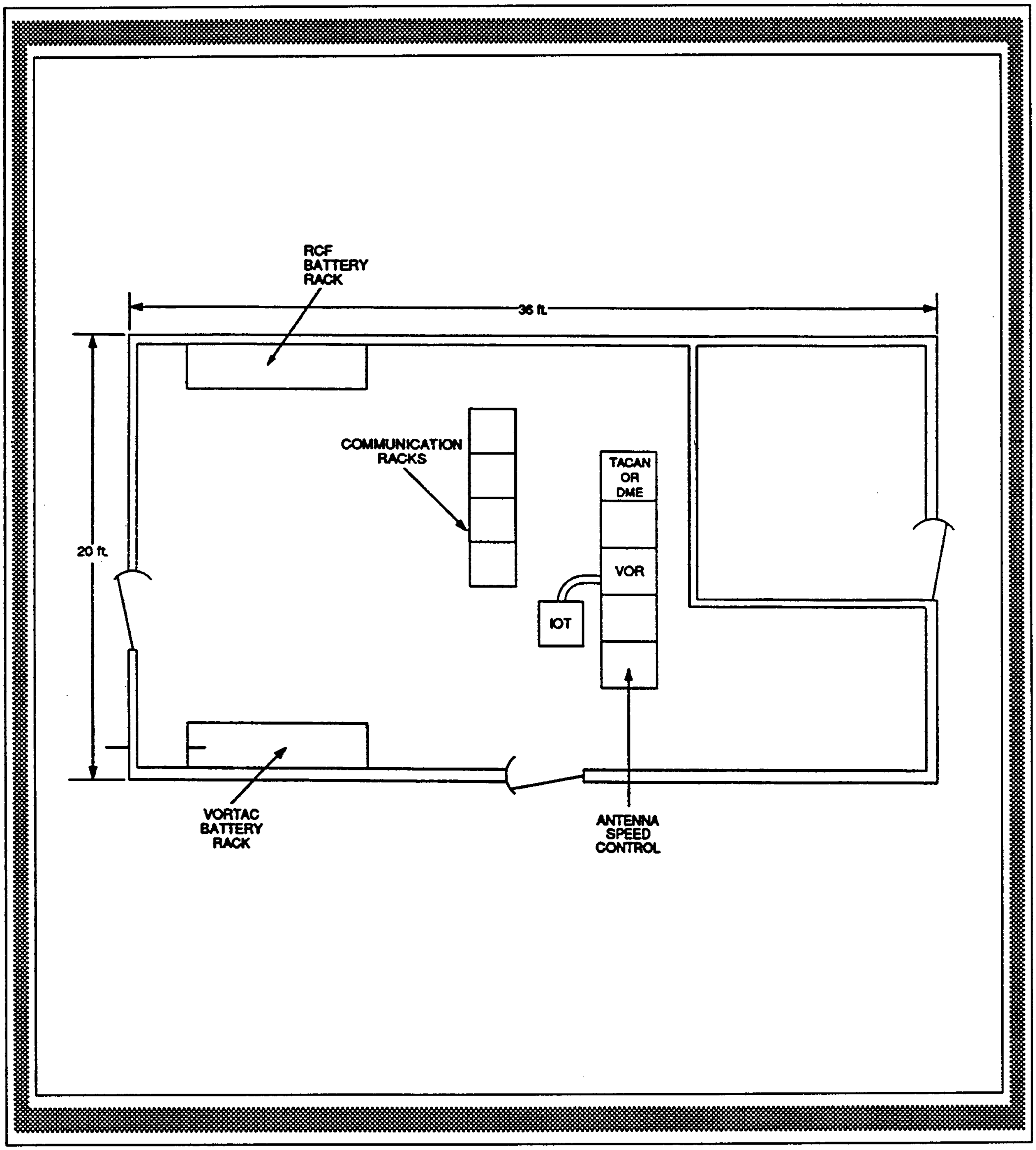


FIGURE 2-16. RCF/VORTAC COLLOCATED IN A 25'x 31' BUILDING

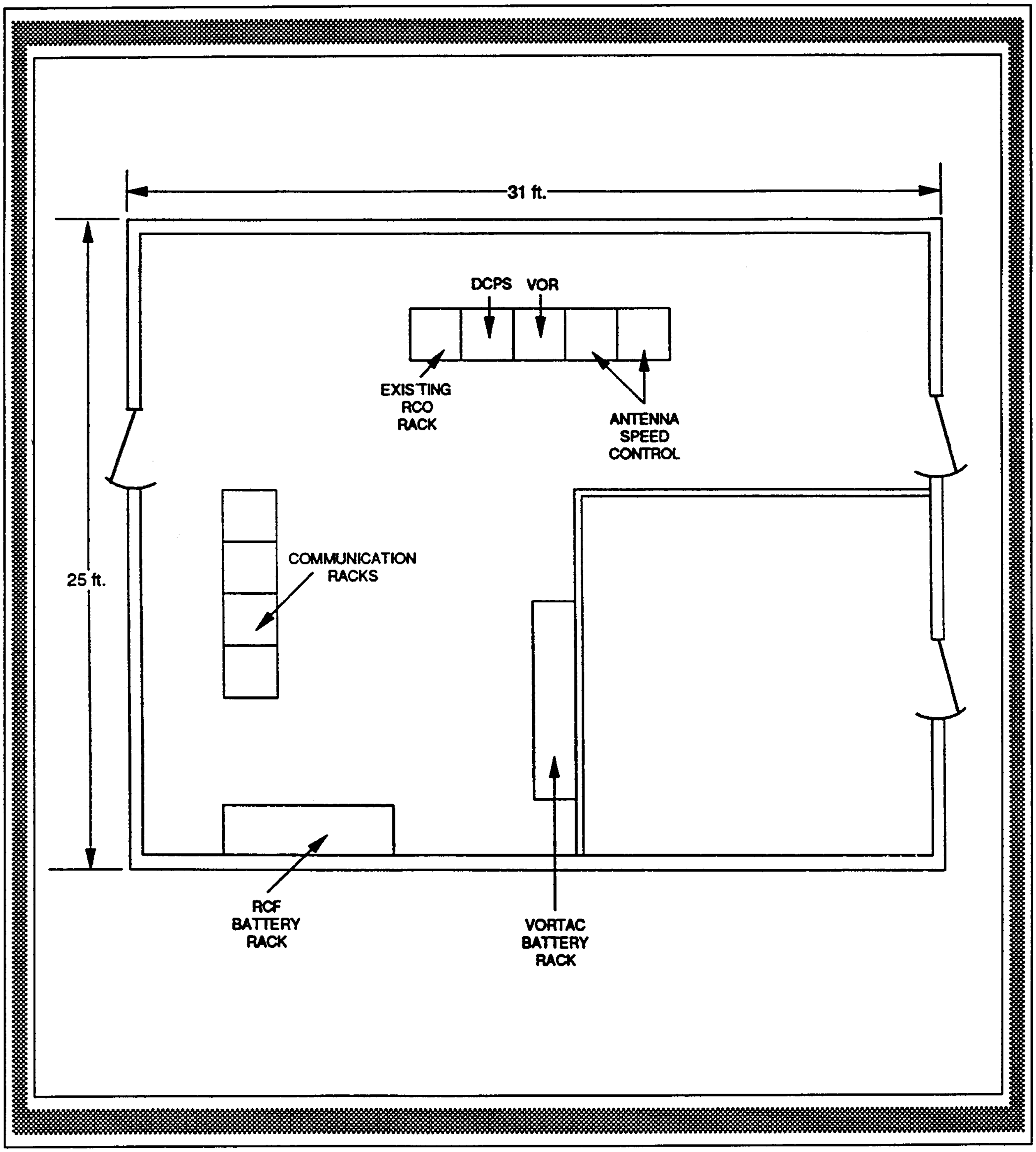


FIGURE 2-17. RCF/VORTAC COLLOCATED IN A 32' DIAMETER BUILDING

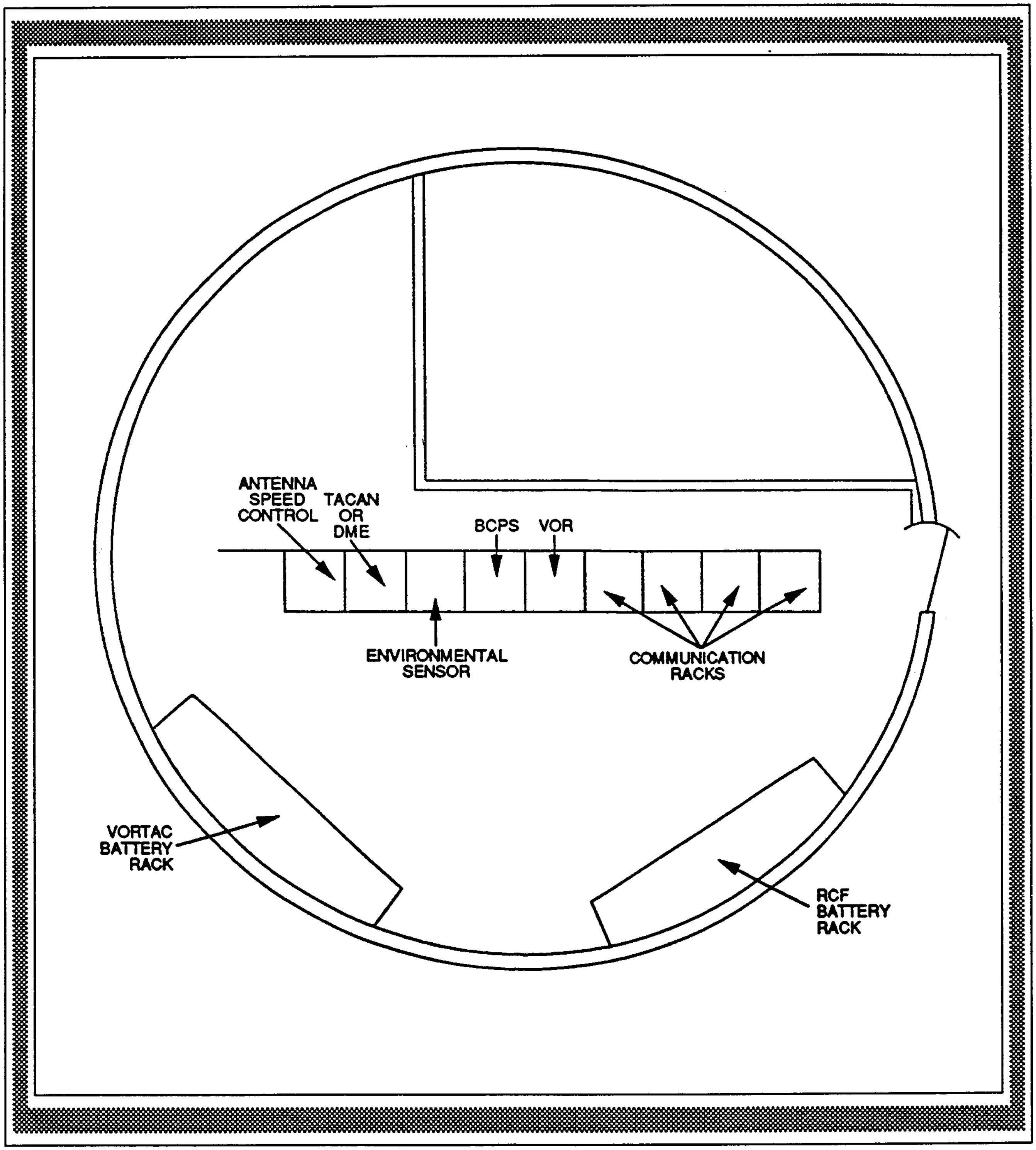


FIGURE 2-18. RCF/VORTAC COLLOCATED IN A 36'x 36' BUILDING

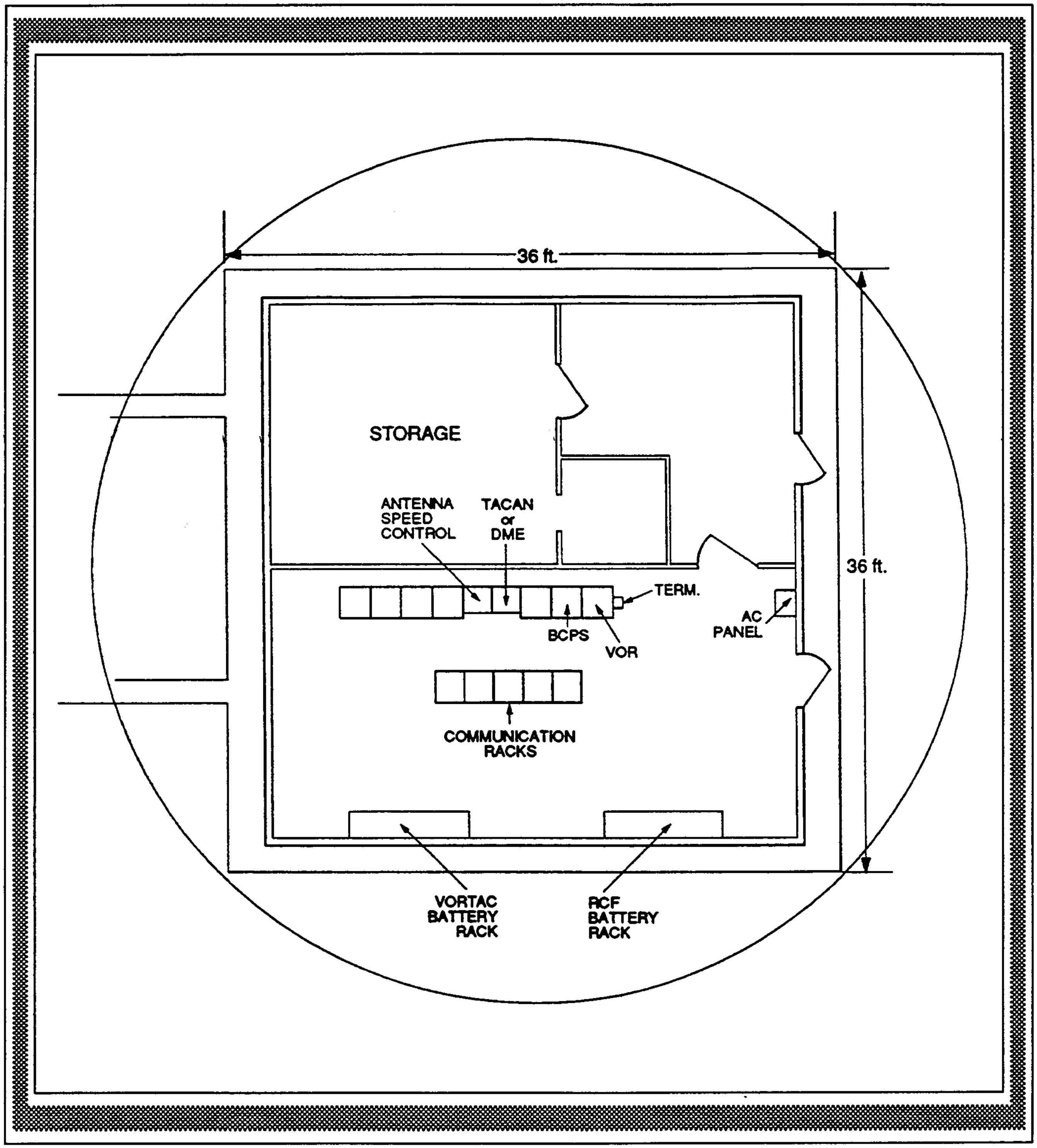


FIGURE 2-19. FUTURE RCF/VORTAC FACILITY

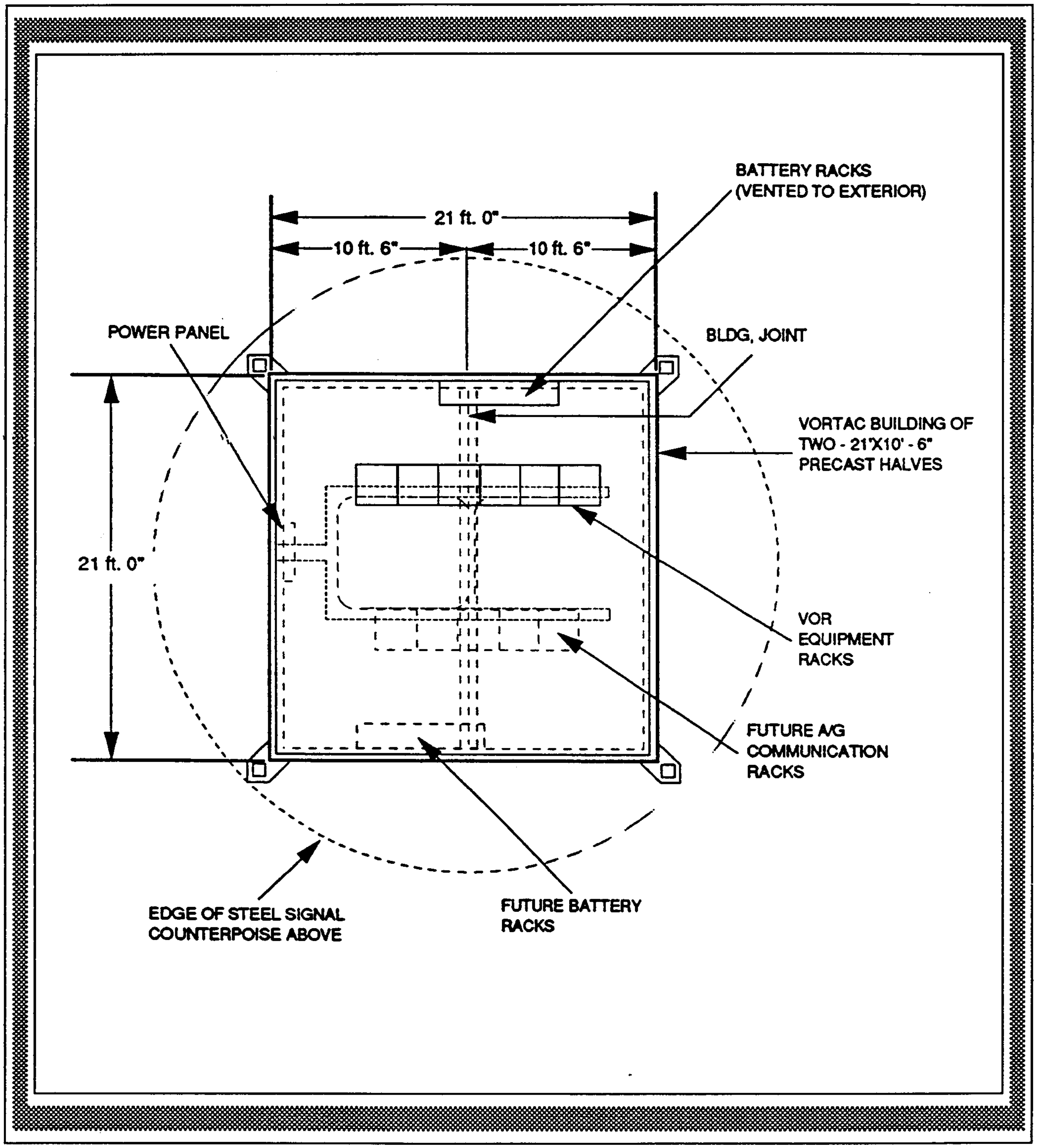
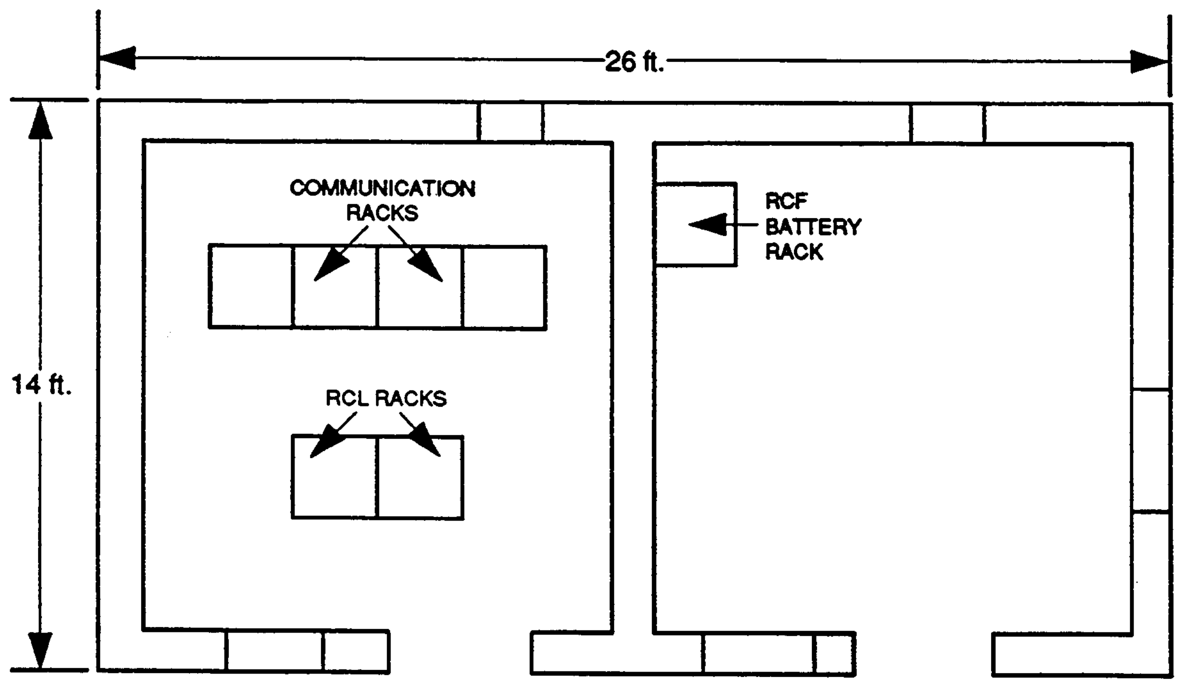


FIGURE 2-20. RCF/RCL COLLOCATED IN A 14'x 26' BUILDING

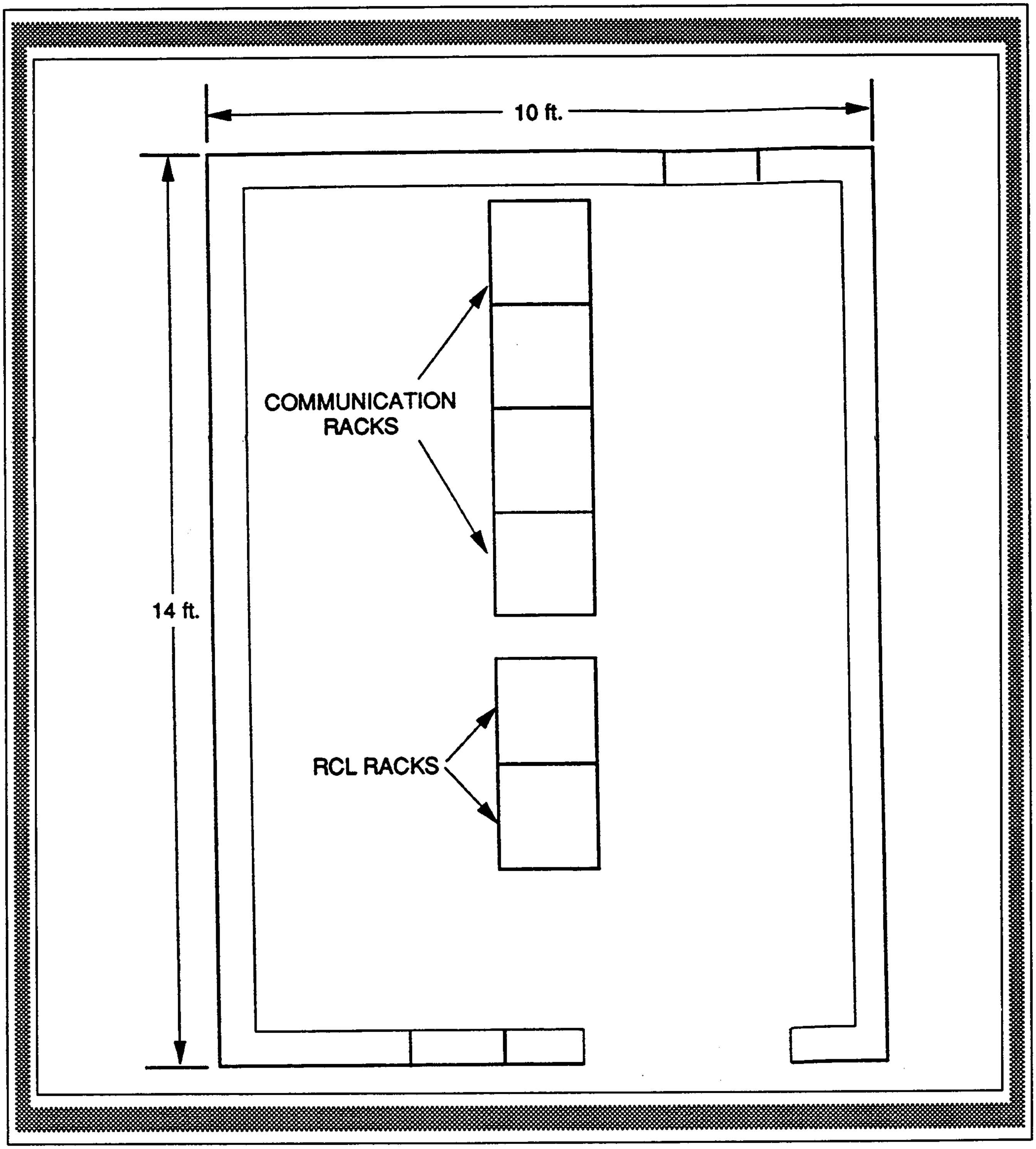


(1) Figure 2-20, RCF/RCL Collocated in a 14'x 26' Building, shows communications equipment racks collocated in an RCF building.

(2) Figure 2-21, Small 10'x 14' RCL Building, shows the layout of a small building.

56.-60. **RESERVED**.

FIGURE 2-21. SMALL 10'x 14' RCL BUILDING



CHAPTER 3. MANAGEMENT OF RCF

SECTION 1. ADMINISTRATIVE

61. **GENERAL.** Several administrative tasks need to be accomplished before the actual installation takes place at any of the RCF. These tasks include the acquisition of land, appropriation of funding, filing environmental impact statements, and securing permits to construct new sites or to modify existing sites. The following sections will address these tasks.

62. **NOTICES TO AIRMEN.** Notices To Airmen (NOTAM) may be used for various actions or pending actions.

a. **Shutdown NOTAM.** The extended shutdown of commissioned facilities undergoing extensive equipment changes, additions, or modernization necessitates the issuance of an advance SHUTDOWN NOTAM. Advance NOTAM's, whenever possible, are normally issued by the regional office where more effective coordination with other groups is possible. This authority may be delegated by the regional office to field installation personnel when the actual shutdown date is contingent upon work progress.

b. **Return to Service NOTAM.** A return to service NOTAM is issued by the regional office after work done to an existing site is completed. A Joint Acceptance Inspection (JAI) may be necessary before a "return to service" NOTAM can be issued.

c. **Commissioning NOTAM.** A commissioning NOTAM is issued by the regional office when a new facility is completed or an existing facility undergoes significant changes. This requires the successful completion of a JAI prior to issuing the NOTAM.

63. **PLANNING.**

a. **Land Acquisition.** Many RCF facilities will be collocated at existing host facilities. When this is not feasible, however, it will be necessary to construct a new facility. Proposed RCF facilities require siting and possible land acquisition. This process includes submitting a legal description and a plot of the site including access roads and utility easements. Proof of conformance to zoning restrictions is also required. This document must be presented prior to requesting the acquisition of property rights. All transactions for acquiring property rights, whether for purchase, lease, or use restrictions, are governed by Order 4660.1, Real Property Handbook. These transactions are handled by FAA real estate office personnel.

b. **Funding.** When land is to be purchased for a new facility site, funds for the purchase shall be included in the region or center Facilities and Equipment (F&E) budget in the same fiscal year as the funds for the facility equipment, installation, and building. This amount is an estimate of the value of the land rights to be acquired, plus acquisition costs and a 15 to 20 percent contingency. Instructions for including land acquisition funds in the annual F&E budget submission are found in Order 2500.55, Call for Estimates - Facilities and Equipment, which is updated annually.

c. **Determination of Need to Acquire.** All possible sites which are found acceptable for the efficient operation of the facility must be considered. Before any action has begun to acquire new land, a determination must be made that the requirements cannot be satisfied by use of property already held by the FAA, property which is accessible to other Government agencies, public land, exchange of Government-owned property for privately-owned property, or the use of existing rights-of-way and easements when available at nominal cost or less.

64. **TASKS.**

a. **Site Investigation.** Prior to conducting investigations and tests, the legal right to enter and use the land must be obtained in writing from the landlord and, if appropriate, the right to clear or otherwise change the character of the land must also be obtained. If verbal authorization is granted, confirmation must be made in the form of a letter with a return receipt. When a landowner will not grant a right of entry, a right of entry must be obtained through the United States (U.S.) courts. Local U.S. attorneys should be consulted through regional counsel in these instances. Contacts with landowners should generally be made by FAA real estate personnel, and when contacts are made by others they must be under the direction of the FAA real estate office.

b. **Environmental Impact Statements.** Environmental Impact Statements (EIS), or a Finding of No Significant Impact (FONSI) shall be approved before negotiations for the acquisition of any land interest begin. Real estate files should contain a copy of the EIS, FONSI, or a reference to the office of record.

c. **Land Office Survey.** It is of prime importance to identify the owners of the land for all candidate sites and obtain the addresses through which they may be contacted. The legal description of land can usually be obtained locally from the city, township, or county clerk's office. Whenever possible, a copy of the deed(s) or other appropriate documentation showing land ownership should be attached to the site survey report. Land adjacent to the proposed sites may be affected by the site zoning restrictions. These restrictions may be determined during the office survey, so that the ownership information of this type of land, may also be included in the site survey report.

d. **Temporary Agreement**. Once the site surveys are completed and it has been decided to field test a specific candidate site, a temporary agreement must be entered into with the property owner(s). This agreement (Permit to Test, Testing License, etc.) will secure entry and access to the property for setting up a portable RCF and testing the site. Contact the regional real estate office of the Logistics Division for specific details concerning these agreements.

e. **Zoning Restrictions**. When the temporary agreement is secured, the landowner(s) should be made aware that zoning restrictions will be required if the site is actually selected. This will reduce the possibility of complications during lease negotiations.

f. **Temporary Permits**. Temporary permits to utilize access roads of adjacent property owners shall also be obtained prior to site testing. An easement is often all that is required to install a permanent access road to a facility, making the actual purchase of land for this purpose unnecessary. Leases or other agreements, as required, should be entered into with appropriate governing agencies or property owner(s) for the use of existing roads. The regional real estate office of the Logistics Division should be contacted for appropriate procedures for entering into such agreements.

65.-69. **RESERVED**.

SECTION 2. TECHNICAL

70. GENERAL. The RCF may be a stand-alone facility or it may be collocated with an FAA-owned host facility, i.e., a control facility, NAVAIDS facility, radar facility, or a RCL. Important attributes to consider when selecting an RCF site include the surrounding topography, ground conductivity, and the amount of ambient electrical noise. An RCF site must be capable of transmitting and receiving a usable signal within its service volume area. Since site conditions may have an adverse impact on the performance of NAVAIDS, radar, or other host facility equipment, coordination is required between the respective program managers of the collocated facility types.

71. DESIGN CONSIDERATIONS. The primary concern of those responsible for siting an RCF is the awareness of potential interference generated in the environment of the proposed site. If the interference encountered during the selection process exceeds the maximum allowable levels, the site shall be removed from the list of candidates.

a. Electromagnetic Interference. EMI is the unintentional radiation from equipment such as microwave ovens, industrial heaters, welding equipment, electronic door openers, etc. Equipment installed in the vicinity of the antenna site is addressed under Federal Communications Commission (FCC) regulations. The regional spectrum engineering office reviews all requests by commercial interests to install RF emitting equipment in the proximity of FAA facilities.

b. Electromagnetic Compatibility (EMC)/RFI. Licensed radio equipment shall be engineered and installed so that no radio interference is experienced at the input to the RCF receivers. The maximum allowable undesired signal level at the input of the RCF receivers from any licensed station is -104 dBm for signals within VHF and UHF bands, and -45 dBm for signals outside the A/G communications RF bands.

(1) RF Interference. Interference pertaining to RF transmitter and receiver sites can be classified into two categories: transmitter noise and receiver desensitization.

(a) Transmitter Noise. This noise is the sideband energy produced by a transmitter. When a transmitter is collocated with a receiver, transmitter noise may cause reduced receiver performance when the noise is greater than the receiver's sensitivity.

(b) Receiver Desensitization. This condition occurs when the transmitter carrier's sideband energy from an on site transmitter spills into the receiver's selectivity band.

(2) Transmitter Generated Noise. The four basic transmitter generated interference sources that can affect communications receivers are shown in the following list.

(a) Transmitter sideband energy.

(b) Spurious transmitter modulation.

(c) Overmodulation of the carrier.

(d) Intermodulation.

(3) Thermal Noise. Receiver sensitivity is theoretically limited to thermal noise which is present in all dissipative materials. Shot noise is also present and is a byproduct of current flow. In some instances pre-selectors used in front of a receiver may introduce noise into the receive system. Bandpass filters having very steep skirts are used at congested sites to accommodate multiple receivers and transmitters. Use of these devices can increase the noise level at the front end of the associated receivers. Proper engineering and judicious use of these devices will prevent surpassing the noise sensitivity of the receivers in use.

c. Siting Criteria. The primary purpose of selecting a site is to provide effective service volume coverage for ATC communications. There are three site characteristics that must be evaluated when selecting a site for A/G communications: surrounding terrain, ground conductivity, and ambient RF noise.

(1) Surrounding Terrain. The topography near the site should not limit radio line of sight. Perfect optical line of sight, although desirable, is not necessary since some refraction takes place at VHF and UHF frequencies. Flat terrain requires evaluation of the effect of ground reflections on the vertically polarized A/G communications signals. Ground reflections predominantly affect A/G communications with high flying aircraft. A concern in evaluating refractions is the effect of terrain at low angles which affects communications with aircraft flying at low altitudes and at maximum range. The lowest altitude will generally be 2,000 feet. The direct ray angle for high altitude approach control characterized by the beam elevation and the beam width is 0.14 degrees. The direct ray angle for extreme range and lowest altitude is 0.72 degrees. These angles are close to horizontal.

(2) Ground Conductivity. Good ground conductivity will improve the low altitude RF coverage at great distances from the site. Conductivity of the soil at a distance of three to five wavelengths around the site is considered good if it is between 0.01 to 0.02 mho per meter. Typical ground conductivity for various types of soil and

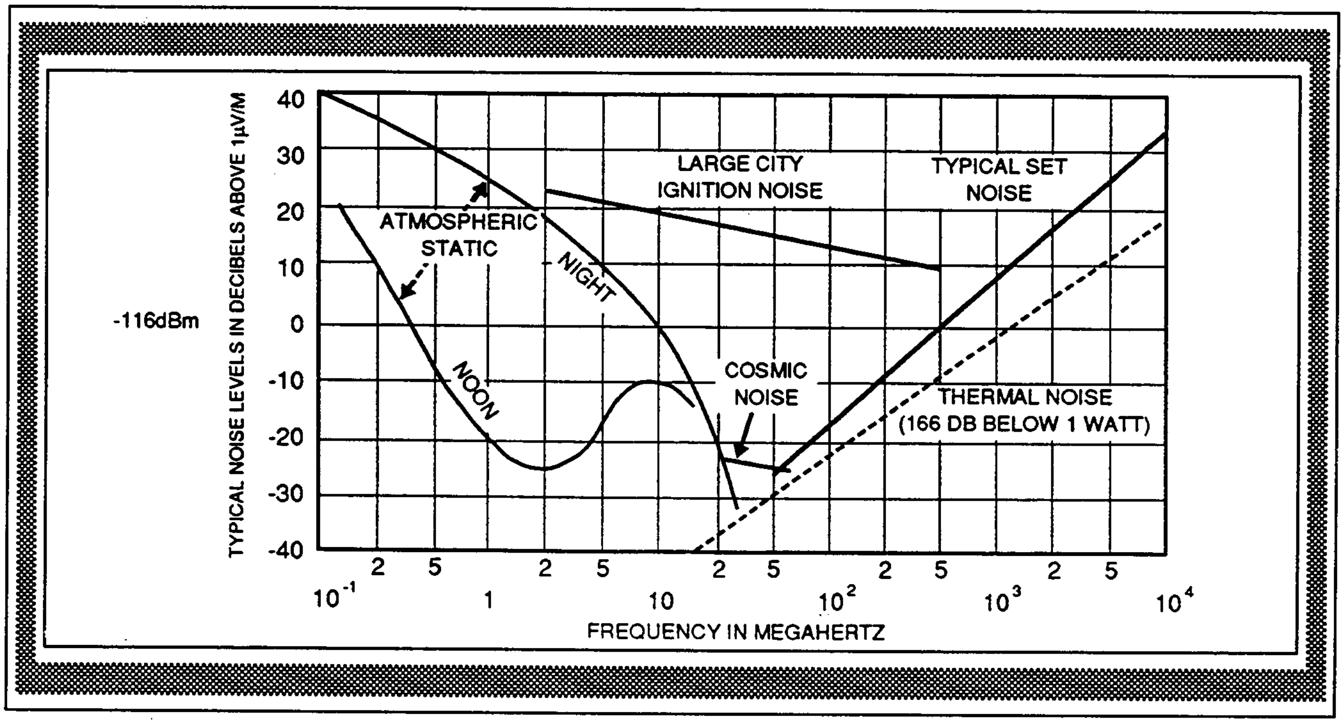
TABLE 3-1. TYPICAL ELECTRICAL PARAMETERS FOR EARTH AND WATER

Earth Type	Conductivity (ó)	Permit-tivity (ë)
Poor	0.001	4.0 to 5.0
Moderate	0.003	4.0
Fair	0.01	15
Average	0.005 to 0.03	10 to 15
Good	0.01 to 0.02	4.0 to 30
Dry	0.00001 to 0.001	2.0 to 5.0
Land	0.002	15
Desert	0.01	3.0
Dry,Sandy, Flat-Typical Coastal	0.002	10
Flat,Wet Coastal Region	0.01 to 0.02	4.0 to 30
Dry Sandy Soils	0.001	10
Pastoral Land	0.005	15
Pastoral Hills, Rich Soil	0.003 to 0.01	14 to 20
Pastoral Medium Hills & Forest	0.004 to 0.006	13
Fertile Soil	0.002	10
Rich Agri. Land (Low Hills)	0.01	15
Rocky Land (Steep Hills)	0.002	10 to 15
Highly Moist Soil	0.005 to 0.02	30
Wet Soil	0.001 to 0.1	5.0 to 30
Marshy Soil	0.1	30
Marshy, Flat(Dense Woods)	0.0075	12
Marshy, Forested, Flat	0.008	12
Low Hills w/Unforested Rich Soil	0.01 to 0.02	4.0 to 30
Mountainous, Hilly(~1000 Meters)	0.001	5.0
Urban Industrial (Avg. Atten.)	0.001	5.0
Urban Industrial (Max. Atten.)	0.0004	3.0
Urban Industrial	0.0001	3.0
Fresh Water	0.001 to 0.01	80 to 81
Fresh Water(10°C at 100.0 MHz)	0.001 to 0.01	84
Fresh Water(20°C at 100.0 MHz)	0.001 to 0.01	80
Sea Water	3.0 to 5.0	80 to 81
Sea Water(10°C at Up to 1.0 GHz)	4.0 to 5.0	80
Sea Water(20°C at Up to 1.0 GHz)	4.0 to 5.0	73
Sea Ice	0.001	4.0
Polar Ice	0.000025	3.0
Polar Ice Cap	0.0001	1.0
Arctic Land	0.0005	3.0 to 5.0

water is shown in Table 3-1, Typical Electrical Parameters for Earth and Water. Refer to paragraph 127, chapter 4, for measurement method guidance. A system of ground conductors can be installed to improve the ground plane near the site if the ground conductivity is less than desirable. The conductors that form the counterpoise/ground plane must not be spaced more than 0.1 wavelength from each other at the lowest operating frequency. This means separation can be no more than 10 inches if the lowest operating frequency is 118 MegaHertz (MHz). Adding moisture-retaining plants and shrubs near the site will improve ground conductivity by increasing the moisture content of the soil. This strategy can be used if ground conductivity is only marginally low. Refer to paragraph 91, Chapter 4, for conductance enhancement guidance.

(3) **Ambient RF Noise**. Both the VHF and UHF A/G communications bands used by the FAA are in a heavily used portion of the radio spectrum. This, coupled with atmospheric noise and manmade noise, contributes to the ambient noise level at A/G communications sites. Typical ambient RF noise levels between 100 KiloHertz (kHz) and 10 GigaHertz (GHz) are shown in Figure 3-1, Typical Average Ambient Noise Level. A noisy RF environment can reduce the effective receiver range at a site.

FIGURE 3-1. TYPICAL AVERAGE AMBIENT NOISE LEVEL



This effect is because the RF noise can mask the desired signals. Also, a receiver's squelch circuit must be set higher than the ambient RF noise level to be effective. The higher the RF noise level, the higher the squelch setting and the stronger the desired signal has to be in order to be received. An evaluation of the RF noise level at a prospective site should be done prior to site selection.

72. **INSTALLATION**. Installation of equipment at an RCF is the responsibility of regional FAA personnel or their contractor installation team. Management of and responsibility for installation may differ depending on whether FAA personnel or contractor personnel are used. Onsite responsibilities for the pre-installation, installation, checkout, verification, and acceptance of the RCF are divided among the various categories of management. Installation responsibilities are divided among the regional office RCF project coordinator, sector office management, the installation team leader, and the installation team in accordance with the regional work order. The onsite assignment of responsibilities of each is general in scope.

a. **Washington Office RCF Project Manager**. The Washington Office RCF Project Manager is primarily responsible for the facilities and equipment. This includes the planning and funding of the program, the development of the program plan, site requirements, installation standards, coordination of regional planning into the national program, and initiation of procurement requests any national equipment procurements.

b. **Regional Office RCF Project Coordinator**. The Regional Office RCF Project Coordinator is primarily responsible for the management of the region's RCF program. This includes initiation of regional actions to implement the RCF program, coordinating material, and site planning. The following are also regional office coordinator responsibilities.

(1) Site preparation prior to the arrival of the installation crew.

(2) Pre-installation testing and verification of the existing equipment.

(3) Completion of all pre-installation tasks.

(4) Assistance to the Technical Onsite Representative (TOR) and contractor or FAA installation team.

(5) JAI.

(6) Local procurements.

c. **Sector Office Management**. Sector office management provides personnel and equipment under the guidance of the TOR's FAA installation team leader. Following are tasks supported by the sector office:

(1) Facility shutdown.

(2) Facility return to service or commissioning.

d. **TOR's Responsibility**. The TOR is the coordinator for the entire onsite contractor installation process and is responsible for ensuring completion of the tasks. Duties include, but are not limited to, verifying the proper pre-installation, installation, checkout, and acceptance of the RCF equipment installation. The TOR will maintain a site log of the installation history. This log includes daily entries for arrival and departure time of contractor personnel, and logging of problems concerning installation, configuration, administration, and management during the project. This log can be used for cross-checking and verifying the contractor's log. Specific duties of the TOR are to ensure that the contractor's tasks listed in subparagraphs (1)-(4) are performed.

(1) Establish and maintain a contractor site log.

(2) Verify and update equipment configuration data.

(3) Install, adjust, and align equipment in accordance with FAA approved technical instruction manuals.

(4) Conduct acceptance tests, Contractor Acceptance Inspections (CAI) and JAI in accordance with FAA instructions.

(5) Complete all necessary forms and records required for facility return to service or commissioning.

The TOR is responsible for ensuring that:

(1) Access to the site is available to the contractor.

(2) Necessary equipment is available to the contractor.

e. **Installation Team Leader**. The installation team leader is the FAA installation team coordinator for the onsite installation process. It is the responsibility of the team leaders to verify the proper pre-installation, installation, checkout, and preparation for acceptance of the RCF equipment installation. The team leader's duties are similar to those of the TOR. Supervision by the team leader, however, is limited to the FAA installation team.

f. **Installation Team**. The installation team is responsible for installation of new equipment in accordance with the instructions of the work order. The installation team is also responsible for the removal and proper packaging for shipment of any old equipment removed during the installation process. Additional duties include the following:

(1) Establish and maintain regional documentation.

(2) Verify equipment configuration and individual serial numbers.

(3) Assist in conducting acceptance tests and logs results in accordance with FAA approved methods.

73. **TESTING AND EVALUATION**. Final testing, evaluation, and acceptance shall be accomplished in accordance with Order 6030.45, Facility Reference Data File, which describes the CAI and JAI. FAA Form 6030-17, Technical Reference Data Record, shall be used to record test data. The contractor is obligated to correct all discrepancies found during the CAI. The contractor is under no further obligation after the JAI is accepted by the FAA. A list shall be kept of all exceptions from the JAI checklist along with its status. The regional office is responsible for the planning and monitoring of this effort. Further details on testing and evaluation of installations is found in Chapter 7, System Test and Acceptance.

74.-78. **RESERVED**.

CHAPTER 4. GROUNDING AND LIGHTNING PROTECTION

SECTION 1. GENERAL REQUIREMENTS

79. **GROUNDING SYSTEM**. Compliance with the RCF grounding and lightning protection requirements provides protection to equipment, improved operation of the communications equipment, and safety to the operators. The reason for installing a ground system for lightning protection is that a lightning discharge cannot be prevented. On the other hand, however, the damage caused by lightning can be minimized. The benefits of a good ground system are realized in the ability to route the lightning currents so that equipment is not damaged and personnel are not harmed. A complete, properly installed ground system is the only way to control the current path of a lightning discharge. This is a much better scenario than being unprepared for a lightning discharge which has the potential to render the site inoperative and injure personnel. The ground system also contributes to the reduction of EMI/RFI and improved EMC. Transmitters and receivers require a good ground reference in order to perform at their designed specifications. Antenna systems also require a properly installed ground system in order to produce the specified radiation pattern. The detrimental effects of ground reflections on RF coverage are increased when an antenna system is not provided with a proper ground system. The major subsystems of the grounding system are the earth electrode system, lightning protection system, multipoint grounding system, and single point ground system. This chapter will provide instructions for meeting the grounding and lightning protection requirements specified in FAA-STD-019b, Lightning Protection Grounding, Bonding, and Shielding Requirements of Facilities.

80. **GROUNDING SYSTEM TERMINOLOGY**. Previously, many terms were used interchangeably. For consistency, underlined titles below are the terms this text will use. Other terms listed are for reference only.

a. **Earth Electrode System Ground**. Other terms commonly used were earthing conductors, counterpoise cable, ring ground, station ground, grounding electrode, and facility ground.

b. **Multipoint Ground**. Other terms commonly used were high frequency ground, equipment ground, chassis ground, and frame ground.

c. **Single Point Ground**. Other terms commonly used were low frequency ground, signal ground, and signal reference ground.

d. **Protection Ground**. Other terms commonly used were safety ground, ground fault protection system, AC ground, and power ground.

81. **GROUNDING SYSTEM DESCRIPTIONS**. RCF facilities contain several identifiable grounding systems. These are described in the following.

a. **Earth Electrode System**. The earth electrode system is a network of electrically interconnecting rods, plates, piping, incidental electrodes (metallic tanks), cables or grids installed below grade external to the facility. The earth electrode system shall provide an electrical connection to earth with an earth-to-electrode resistance equal to or less than 10.0 ohms. The earth electrode system is connected by a single large cable to the internal facility main ground plate providing a common, low resistance electrical path to earth ground.

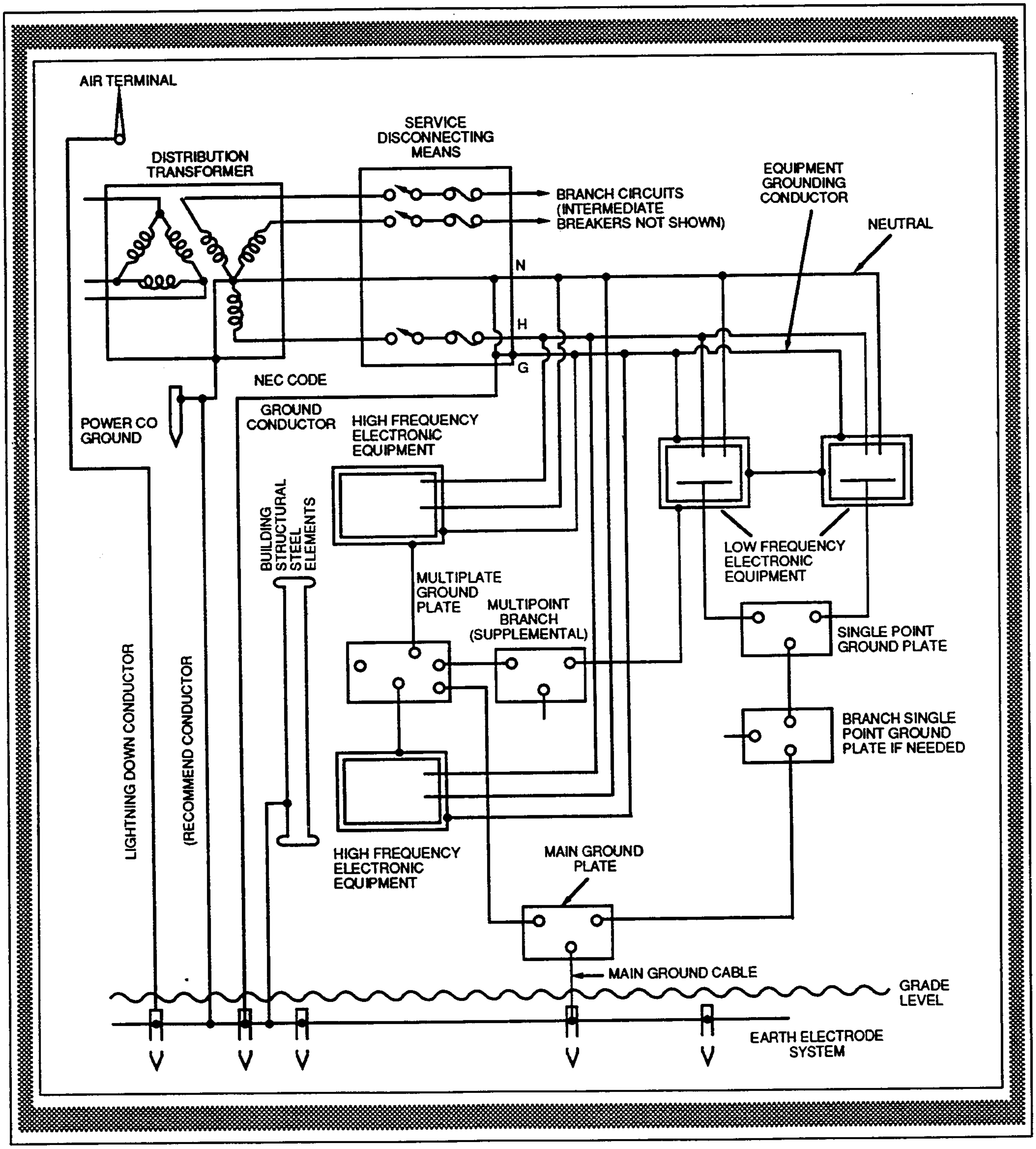
b. **Lightning Protection System**. A lightning protection system shall be provided for all structures through the use of air terminals and their associated down conductors, which provide a low resistance electrical path to the earth electrode system. Transient and surge suppressors shall be used on incoming facility conductors and on cables interconnecting widely separated equipment or facilities in order to prevent damage from lightning induced power surges. The lightning protection system electrical path shall exhibit a low impulse impedance to reduce transient potentials and provide high power transfer capability to dissipate energy to earth.

c. **Multipoint Grounding System**. An internal facility grounding system shall be implemented with a multipoint grounding system. This system provides low resistance, high frequency multiple electrical paths via the main ground plate to the earth electrode system. All equipments and chassis grounds shall be connected to this system. The reference color for the multipoint ground conductor is green with an orange tracer. The grounding system shall provide a low resistance return path for electrostatic charge and potential differences on chassis ground to near earth potential. A typical grounding system is illustrated in Figure 4-1, Typical Facility Grounding System.

d. **Single Point Ground System**. A single point ground system shall be provided by an isolated and separate electrical path grounding system. This system provides a separate low resistance, low frequency path via the main ground plate to the earth electrode system. The reference color for the signal ground conductor is green with a yellow tracer. The single point ground system shall provide a ground reference for signal voltages and a low resistance conductor path to ground independent of static charges common in alternating current (AC) power and equipment protective ground.

e. **Protection Ground**. The protection ground shall be provided by a separate path grounding system. This ground shall be part of the AC power wiring system and shall be included with all AC voltage conductors (black and white) as the third (green) wire.

FIGURE 4-1. TYPICAL FACILITY GROUNDING SYSTEM



The protection ground provides protection to personnel and equipment from electrical distribution faults or unintentional connections. The protection ground system shall join the electrical neutral at the service disconnecting panel.

82. **EMI**. EMI is a term used generally to include all applicable interference to electronic equipment. Included also are the terms RFI, Electromagnetic Pulse interference (EMP), and equipment characteristics of EMC. Requirements for compliance and testing are found in the following specifications, standards (STD) and manuals:

a. FAA-G-2100e, Electronic Equipment, General Requirements.

b. FAA-STD-020b, Transient Protection, Grounding, Bonding and Shielding Requirements for Equipment.

c. MIL-STD-461C, Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference.

d. MIL-STD-462, Electromagnetic Interference Characteristics, Measurement of.

e. MIL-STD-463A, Definitions and System Units, Electromagnetic Interference and Electromagnetic Compatibility Technology.

f. MIL-STD-454, Standard General Requirements for Electronic Equipment.

g. NTIA Manual, National Telecommunications and Information Administration, Regulations and Procedures for Radio Frequency Management.

83. **TRANSIENT PROTECTION**. Surge and transient protection shall be provided on all coaxial cables, paired signal landlines, and AC power lines entering or leaving a facility or interconnecting widely spaced equipment within a facility. The facility grounding system is a vital part of equipment, coaxial cable, and signal landline protection. The AC power ground must meet the National Electric Code (NEC) Article 250 requirements. Further topic discussion can be found in section 6.

84.-87. **RESERVED**.

SECTION 2. EARTH ELECTRODE SYSTEM

88. **GENERAL**. The RCF equipment requires an effective earth electrode system for the facility to function properly. The earth electrode system provides a source of ground potential so that all ground conductors connected to it safely dissipate stray currents. The earth electrode system for the RCF shall be in accordance with FAA-STD-019b. If an RCF is collocated with a host facility such as a NAVAIDS or radar site for example and the host facility meets the requirements of FAA-STD-019b, the RCF shall utilize the host facility's earth electrode system. If the host facility does not have an earth electrode system which meets the standards, the earth electrode system shall be upgraded.

89. **ENVIRONMENTAL CONDITIONS EVALUATION**. The following conditions shall be ascertained before a new ground system is planned for an RCF.

a. Type of terrain; i.e., soil or rock.

b. Type and condition of subterranean soil.

c. Location of site; i.e., wetland or flood zone.

d. Depth of frost line.

Normally, this information is readily available for an existing site; however, a new site may require borings to determine the condition of the subterranean soil. If a tower is planned for a new site, soil borings will have to be done prior to designing the tower foundation. The information gathered from these borings is adequate for assisting in the design of an earth electrode ground system. When a communications tower is not planned, soil borings shall be done in the vicinity of the planned RCF.

90. **EARTH RESISTANCE**. Earth resistance test measurements shall be made of the surrounding earthen area of the site where the earth electrode system is to be installed. An earth electrode ground system resistance of 10.0 ohms or less to ground needs to be established for proper operation of the system. Several options can be implemented regarding the type of ground system to use and treatment of the soil if measurements show that the required predicted earth resistance is not met. Analyses and calculations are contained in Order 6950.19, Practices and Procedures for Lightning Protection, Grounding, Bonding, and Shielding Implementation.

91. **DESIGN PARAMETERS**. The elements of an earth electrode system are the ground conductors and the earth penetration devices. These elements are in the form of copper wire conductors and copper rods

which are placed under ground, above ground, around structures and around towers. This grounding system is connected to the structure and tower air terminals, structure steel, fuel tanks, water lines, facility main ground plate and the AC power system neutral. The type of earth electrode system used will differ in design depending on the conditions at the site. When an RCF is located on a rock surface, the usual method of sinking rods into the ground and burial of conductors to provide earth ground will not be possible. In this instance, a ground plane over the rock surface shall be constructed. Chemical enhancement of the soil can be used to increase conductivity of the ground system when soil conditions make it impossible to achieve an earth-to-electrode resistance of 10.0 ohms or less.

a. <u>Ground Rod System</u>. The standard RCF earth electrode system consists of ground rods, grounding conductors, an earth electrode counterpoise, and a main ground plate. The earth electrode counterpoise is the underground interconnecting conductor. This conductor shall be No. 4/0 American Wire Gage (AWG), stranded bare copper wire, used to connect the ground rods in a rectangular or circular array. Ground rods shall be composed of copper-clad steel or solid copper and shall be a minimum of 10 feet long and 3/4 inch in diameter. They shall have a threaded surface so that more than one rod may be connected together where applicable for deeper penetration into the earth. The earth counterpoise conductor shall be positioned at least 2 feet below the ground surface. The tops of ground rods shall not be less than one foot below the ground surface. All connections to the earth electrode system shall be exothermic welds. The earth electrode system shall have a resistance in the earth of 10.0 ohms or less, as measured in accordance with FAA-STD-019b, and described in section 6 of this chapter.

(1) <u>Depth of Penetration</u>. The depth to which ground rods are driven depends on the conductivity of the soil, the level of the water table at the site, and the distance between rods. Penetration into a permanent water table is most desireable. In northern parts of the country, rods shall extend below the frost line where possible. This could mean driving rods to a depth of 30 feet in some instances. Driving a ground rod farther into the soil to reach a water table is recommended when the upper portion of the rod lies in soil with a low moisture content or in poorly conductive soil such as sand or permafrost. If a ground rod assembly is driven deep into good conductive soil, the upper 10 feet will conduct a majority of the initial current. This limits the flow of current further down the rod. Therefore, when soil conductivity and moisture content are high, grounds rods should not extend beyond 12 feet below the surface.

(2) <u>Number of Rods and Spacing</u>. The number of rods used at a site is dependent on the requirement to satisfy the earth-to-electrode resistance. A general rule for determining distance between

ground rods is that the distance between rods shall be greater than their length. The closer the ground rods are spaced, the higher the interconnecting inductance. A chart which compares the change in resistance with respect to the number of rods used and the distance between them is shown in Figure 4-2, Change in Resistance vs Number and Spacing of Rods. All sites will require more than five grounding rods.

(3) __Interconnection of Rods__. The ground rods shall be interconnected with copper cables. These conductors shall be No. 4/0 AWG stranded bare copper wire with joints made with exothermic welds. The interconnecting conductor shall be buried at least 2 feet below the surface. In areas where the frost line is below this level, the conductor shall be buried below the frost line, if practical.

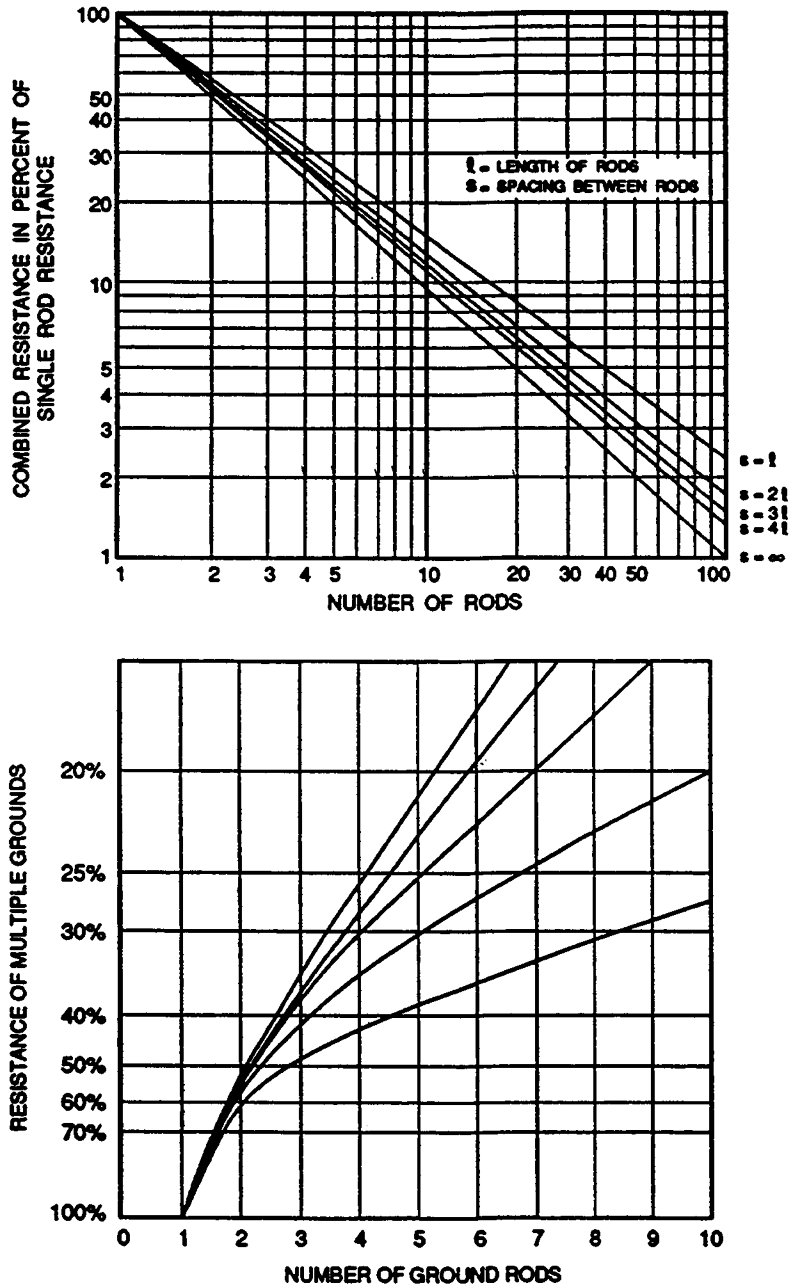
b. __Alternative Ground Plane System__. An alternative ground plane system uses wires or large copper straps spread out over sandy or rock surfaces in the form of radials. These conductors are buried underground or laid over the surface and anchored with ground rods. The underground conductors are buried at least 2 feet, or below the frost line, which ever is deeper. With the addition of the conducting radials, the rocky surface will carry a surface charge creating a large area over which lightning will dissipate.

(1) __Underground System__. Horizontal bare conductors buried under the ground in a radial or grid configuration can produce an earth-to-electrode resistance of less than 10 ohms. In poor or layered soil, ground rods may be needed in addition to radials or a grid in order to reduce the resistance. Increasing the number of conductors does not automatically reduce the resistance unless the conductors are spaced to minimize mutual interference between conductors. In addition, the transient impedance of each vertical ground rod and each conductor in a grid must be assessed so the safe limit for step voltage is not exceeded. The underground system designer should refer to Order 6950.20 for more design references.

(2) __Above Ground System__. Conductors on top of a rocky surface must be made shorter than conductors buried under ground. The accumulated inductance on long conductors limits surge currents from propagating the length of the wire. In this situation, a greater number of conductors of shorter length is needed to satisfy the requirements of the earth electrode system. Flat strap copper is better for the above ground conductors if conditions permit its use.

c. __Chemical Enhancement__. Chemicals added to the soil to improve conductivity effectively increase the capacity or volume of the soil to dissipate electrical currents from lightning strikes. Adequate amounts of chemicals should be used to allow for the effects of dilution from rainwater and runoff. It takes approximately 40 to

FIGURE 4-2. CHANGE IN RESISTANCE vs. NUMBER AND SPACING OF RODS



90 pounds of chemical in the application to attain the increased soil conductivity. This application will be maintained for 2 to 3 years. See manufacturer instructions as to required application surface area. The effect of chemical treatment is shown in Figure 4-3, Effect of Chemical Treatment on Resistance of Ground Rod System. The effect of seasonal resistance variations of chemically treated soil versus untreated soil is also shown in figure 4-3. Chemical gels shall not be used as a conductivity enhancement in surface grounding systems at RCF sites.

92. <u>INSTALLATION</u>.

a. **<u>Pre-installation Tasks</u>.** Before work begins, a schedule shall be established so that site excavation will coincide with the hole and trench digging necessary for earth electrode system installation.

b. **<u>CAUTIONS</u>.** The following task cautions shall be addressed prior to installation.

(1) Prior to upgrading the earth electrode system, request the issuance of a NOTAM and coordinate all systems shutdowns with air traffic personnel.

(2) To avoid injury to personnel and any possible equipment damage, turn off the AC power at the service entrance disconnect, and if possible, at the transformer.

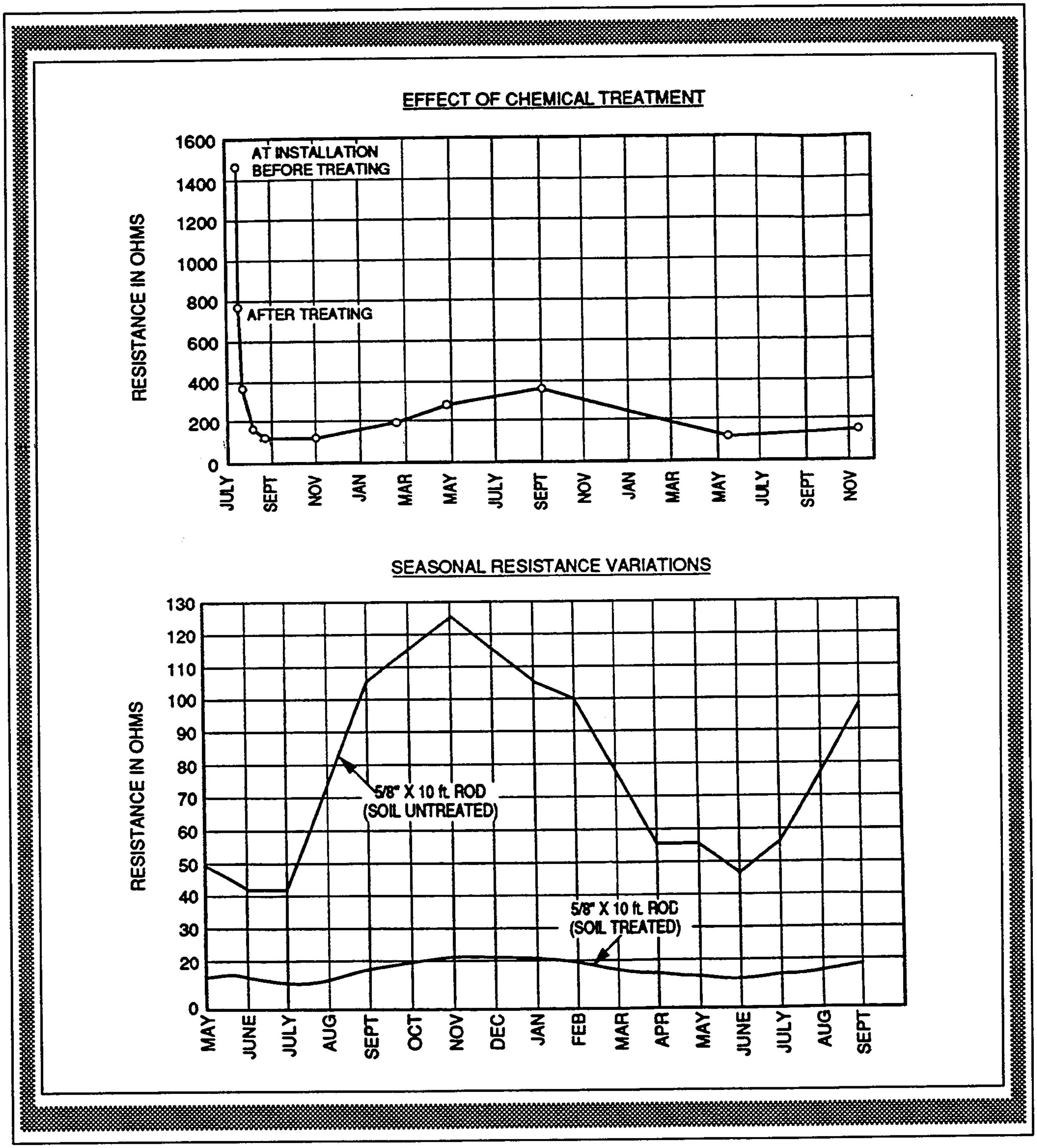
(3) To avoid damage to existing buried cable, contact the appropriate personnel before digging holes and/or trenches.

(4) Hand digging tools shall be used in uncertain cabling locations to avoid damage to existing buried cable. No power digging equipment shall be used.

c. **<u>New Earth Electrode System</u>.** Specific site conditions will dictate the type of grounding system applicable to the RCF and the action necessary to meet the required earth-to-electrode resistance.

(1) **<u>Ground Rod Location</u>.** Ground rods shall be driven into undisturbed or compacted earth. If rods must be located in gravel drainage areas, the rods shall extend at least 8 feet into undisturbed earth beneath the drainage area. The assumption is that the drainage area is dug below the average ground level. In northern areas the ground rods shall be driven so that 10 feet of the rod assembly extends below the frost line. The rods are driven into the earth either by hand or with a driving rig. A driving stud shall be used to protect the threaded end of the rod when it is being driven into the ground.

FIGURE 4-3. EFFECT OF CHEMICAL TREATMENT ON RESISTANCE OF GROUND ROD SYSTEM



(2) **Interconnecting Cable**. Interconnecting cable shall be attached to a ground rod by exothermic welding normally. Only exothermic welds are used when the interconnecting cable ground rod connections are to be covered with earth and are to be inaccessible. Underwriters Laboratory (UL) approved clamps may be used in an access well, with the exception that a down conductor directly from an air terminal always requires an exothermic weld. Clamp connections are permissible only in access wells because there they can be inspected periodically for maintenance. An example of a tower and structure earth electrode system is shown in Figure 4-4, Typical RCF Earth Electrode System. Use of an interconnected solid copper strap grid or star does not preclude the normal use of No. 4/0 AWG perimeter cable.

(a) **Trenches**. In new installations a trench is dug for the interconnecting cable around the building from two to six feet from the outside wall. Another trench is dug up to the facility main ground entrance junction box where the cable will be installed. The trenches are dug 2 feet deep in most cases. In northern areas where the frost line is at a depth greater than 2 feet, the trenches are dug deeper than the frost line.

(b) **Rod Connections**. Connections to the ground rods are made by exothermic welds using the proper size splicer molds and cartridges. An illustration of the steps involved in this procedure is shown in Figure 4-5, Exothermic Welding Process, and Figure 4-6, Ground Rod Welds.

(3) **Access Wells**. Access to the earth electrode system may be provided by the use of access wells. These wells are constructed of clay or concrete pipe with a hinged or removable cover plate. When an access well is located at the junction of a ground rod and an air terminal down conductor the bond shall be a exothermic weld. When the grounding system is located underneath a structure, the access wells may be located on the inside floor of the structure. One of the wells however, should be located near an area of undisturbed earth so that earth resistance measurements can be made for earth electrode system proof of performance testing. Figure 4-7, Details of Ground Rod/Interconnection Cable Installation, and Figure 4-8, Grounding Access Well Construction, show details of access well installation.

(4) **Earth Resistance Measurements**. Resistance measurements shall be made as each ground rod is installed to ensure that it meets the requirements for a low-resistance electrical path to ground. If the resistance is greater than required, the rod should be driven deeper into the earth or relocated. In order to drive the rods deeper, section(s) are added as needed by using a coupler attached to the threaded end of the ground rods. Test each ground rod after it is installed using the procedure described in Section 7, Testing.

FIGURE 4-4a. TYPICAL RCF EARTH ELECTRODE SYSTEM

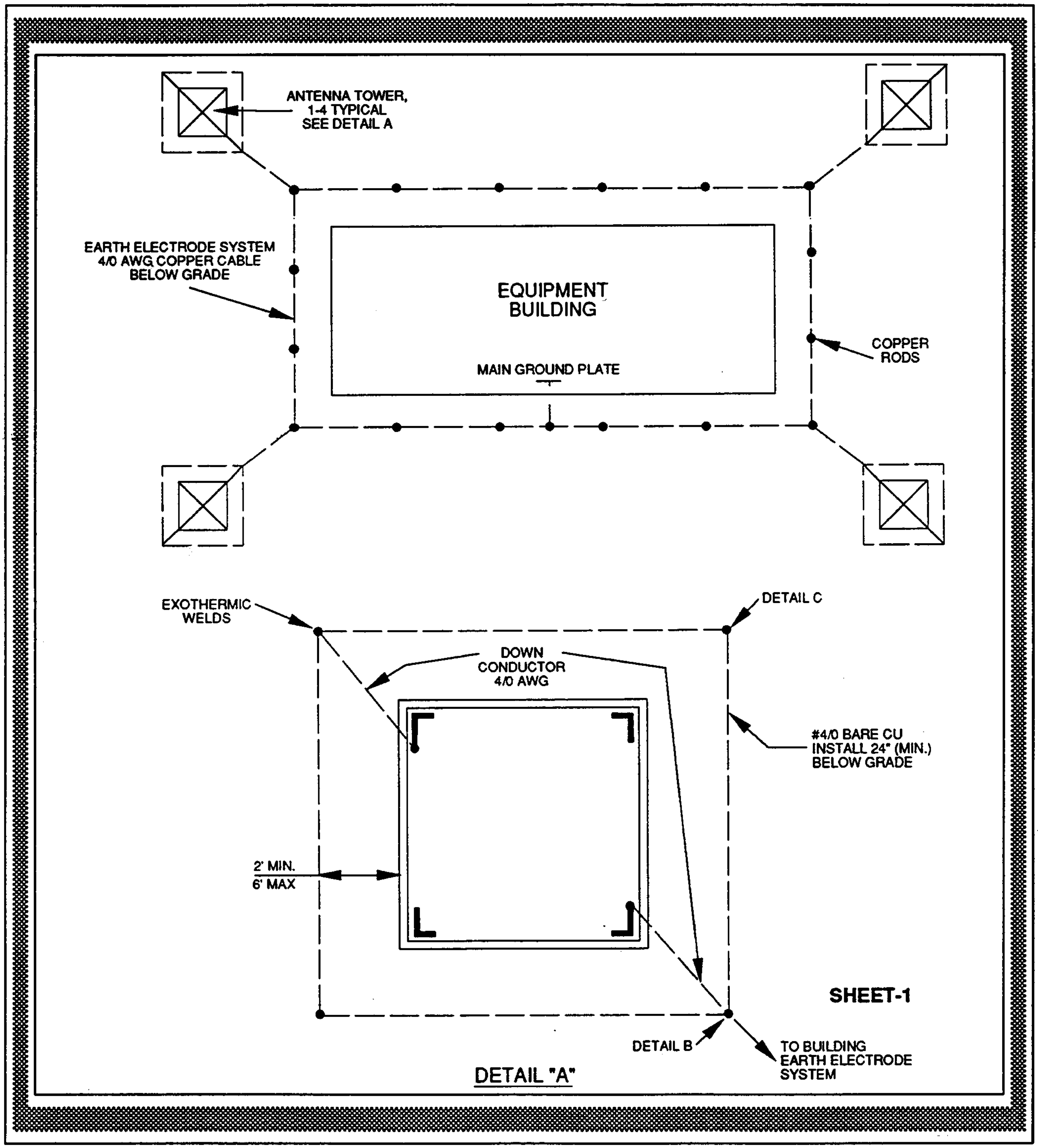


FIGURE 4-4b. TYPICAL RCF EARTH ELECTRODE SYSTEM

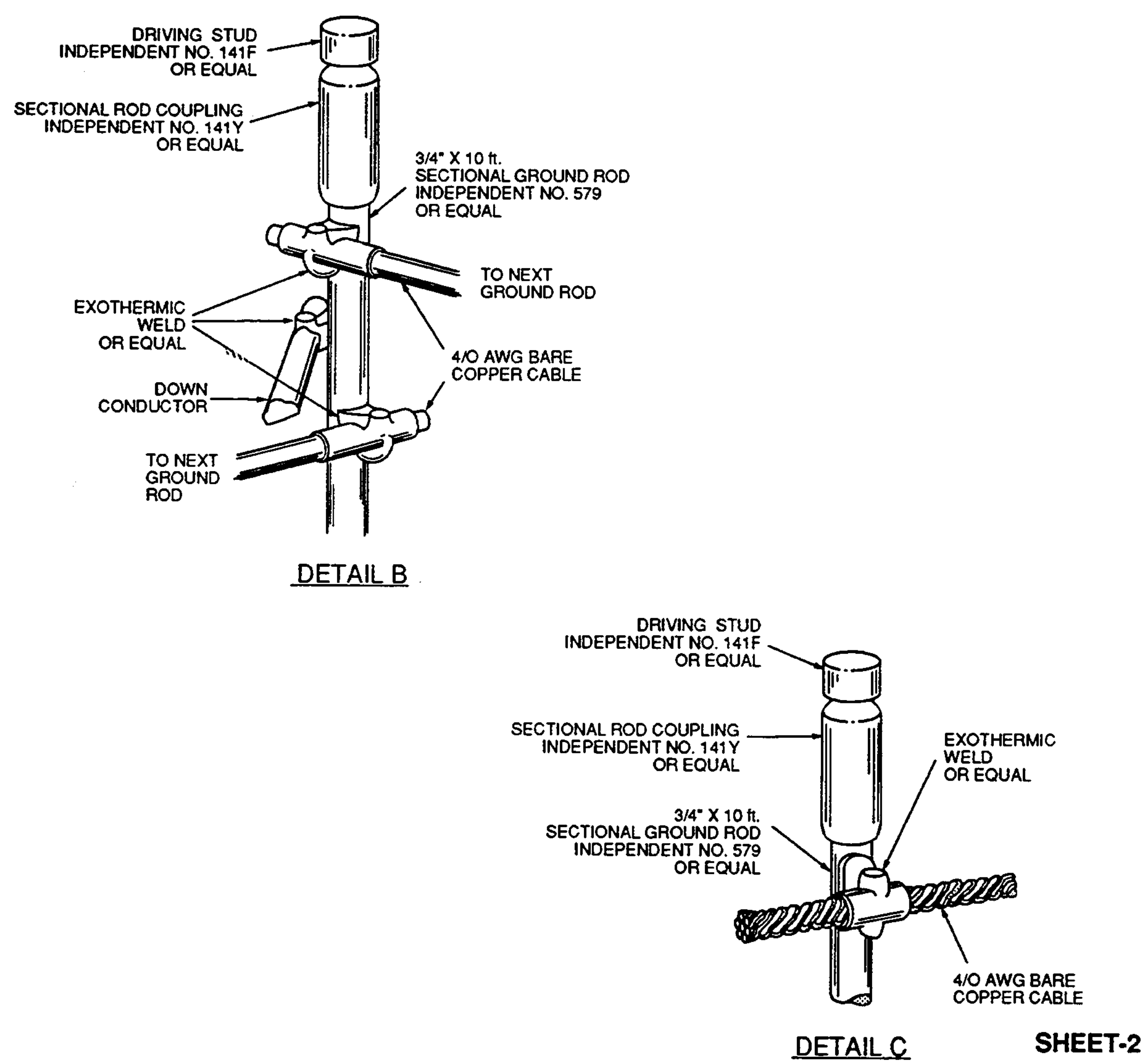


FIGURE 4-5. EXOTHERMIC WELDING PROCESS

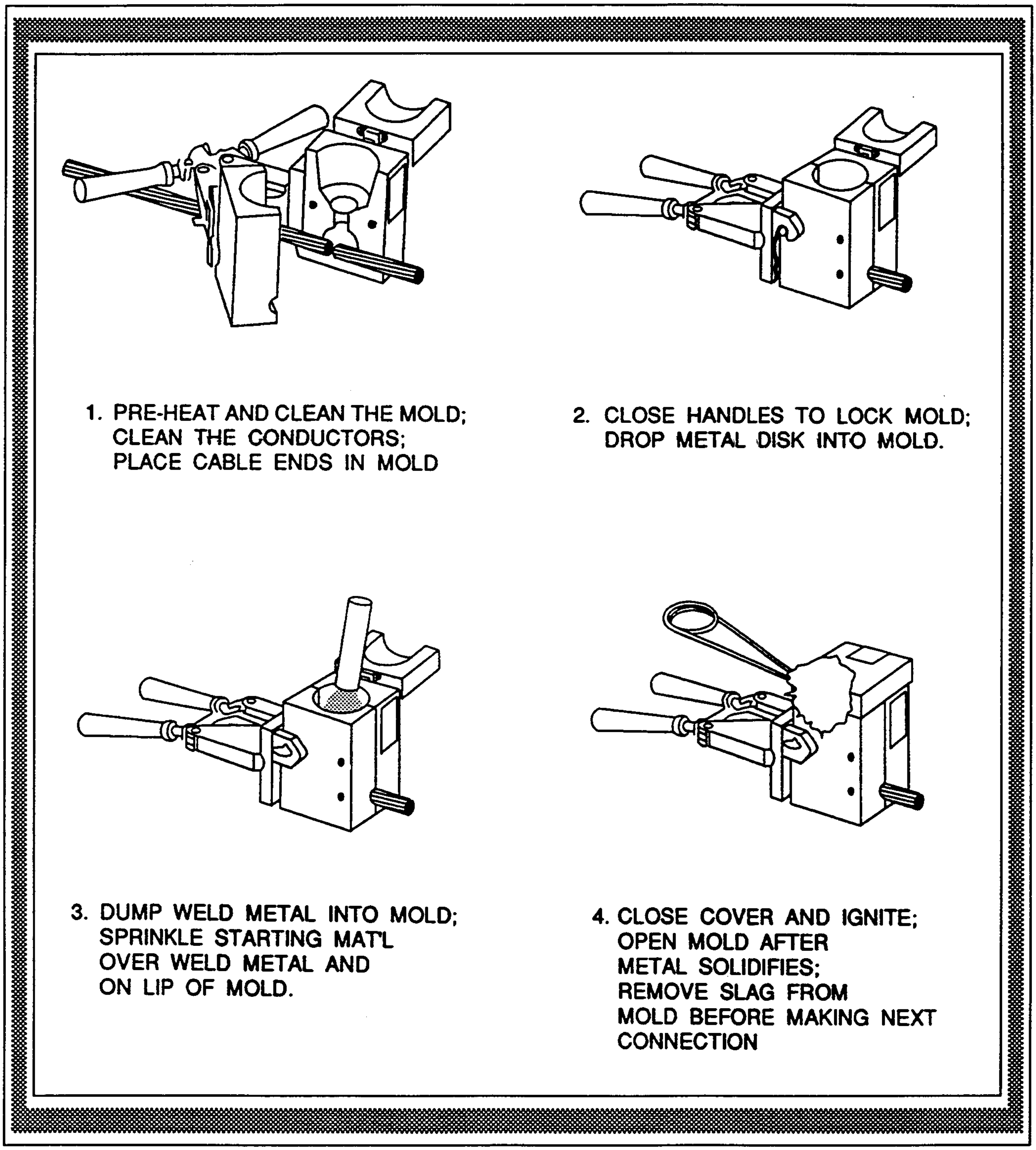


FIGURE 4-6. GROUND ROD WELDS

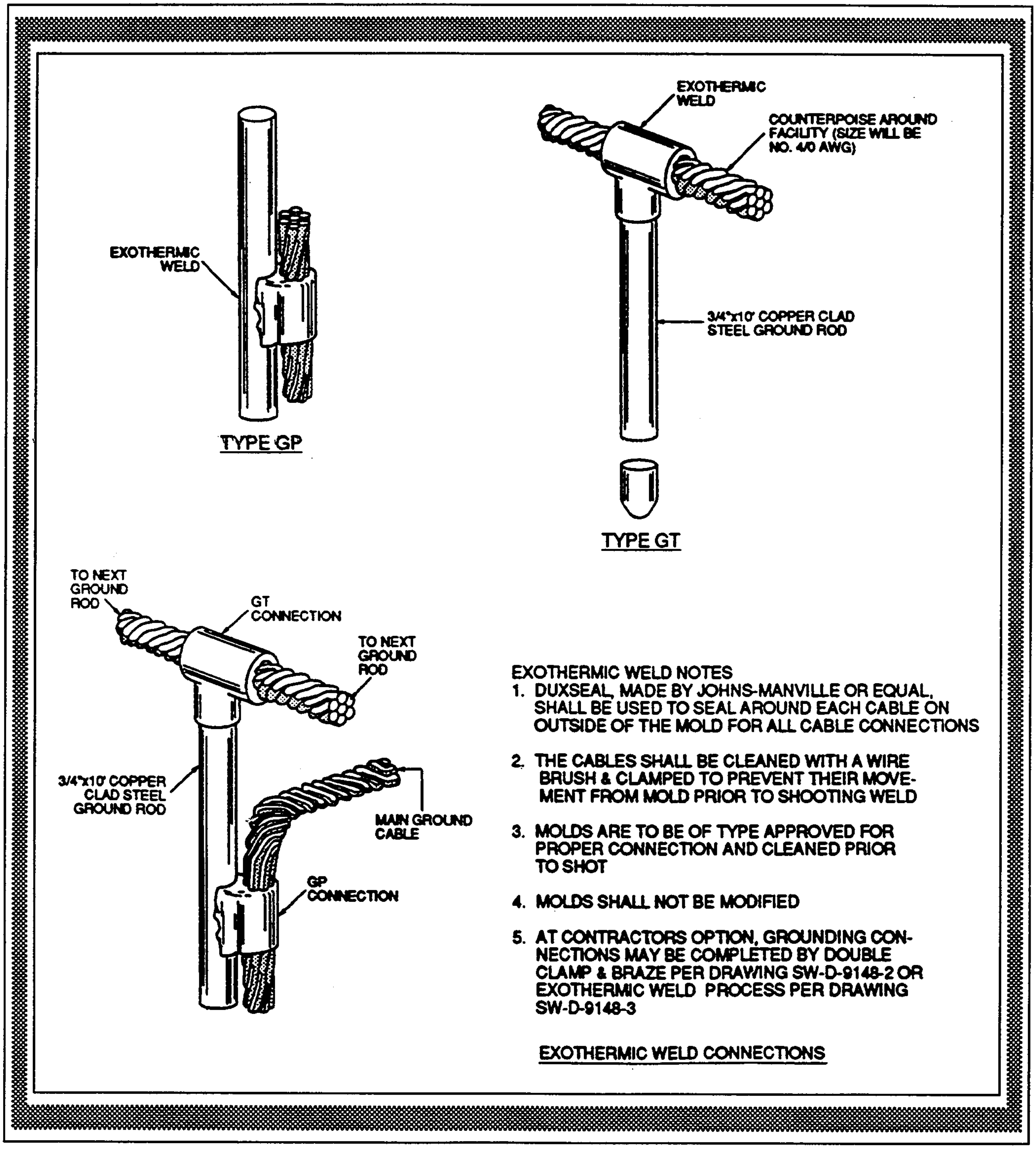


FIGURE 4-7. DETAILS OF GROUND ROD/INTERCONNECTING CABLE INSTALLATION

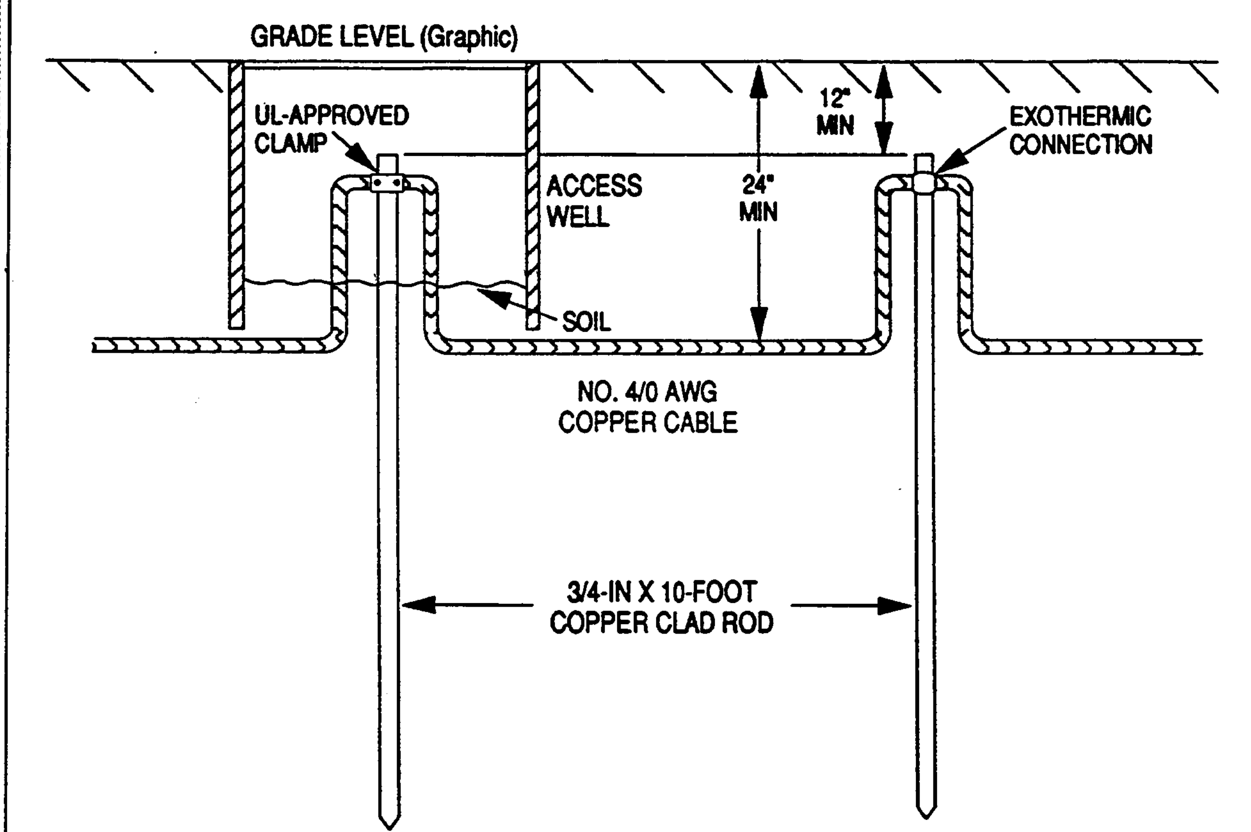
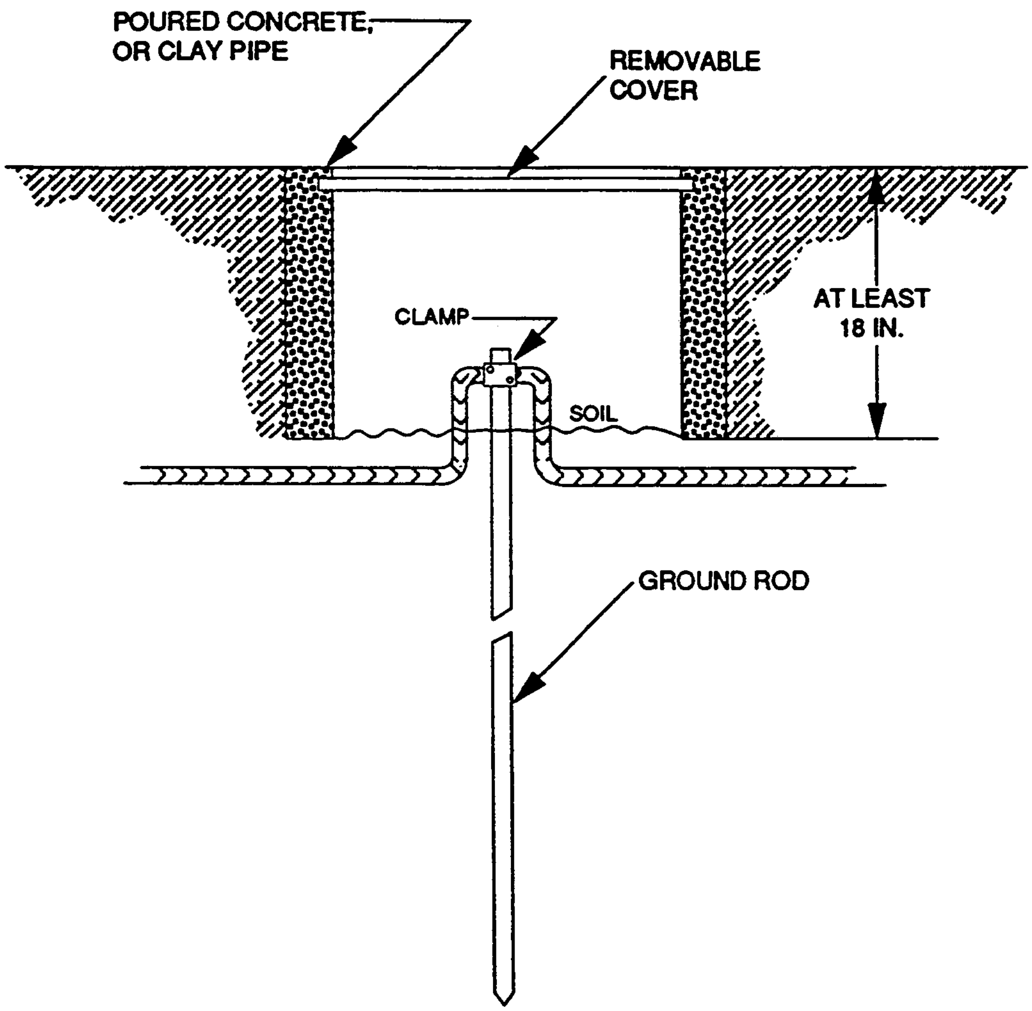


FIGURE 4-8. GROUNDING ACCESS WELL CONSTRUCTION



d. **Repairing Existing Earth Electrode System**. If the average earth ground resistance of the existing earth electrode system exceeds a nominal value of 10.0 ohms, make a trench with hand tools to uncover the copper interconnecting conductor and ground rod joints for complete inspection. A general picture indicating parts of the earth electrode system to be examined is shown in Figure 4-9, Connection to Earth Electrode System.

(1) **Interconnecting Conductor**. An inspection is to be made of the existing interconnecting conductor to ensure it is No. 4/0 AWG bare stranded copper. Examine the conductor throughout its length for breaks. Ensure good electrical and physical conductor bonds are present at the existing ground rods. Faulty welds shall be repaired using an exothermic No. 4/0 size cable splicer mold and the weld metal compound. Retest the earth electrode system after the interconnecting cable has been inspected and properly repaired.

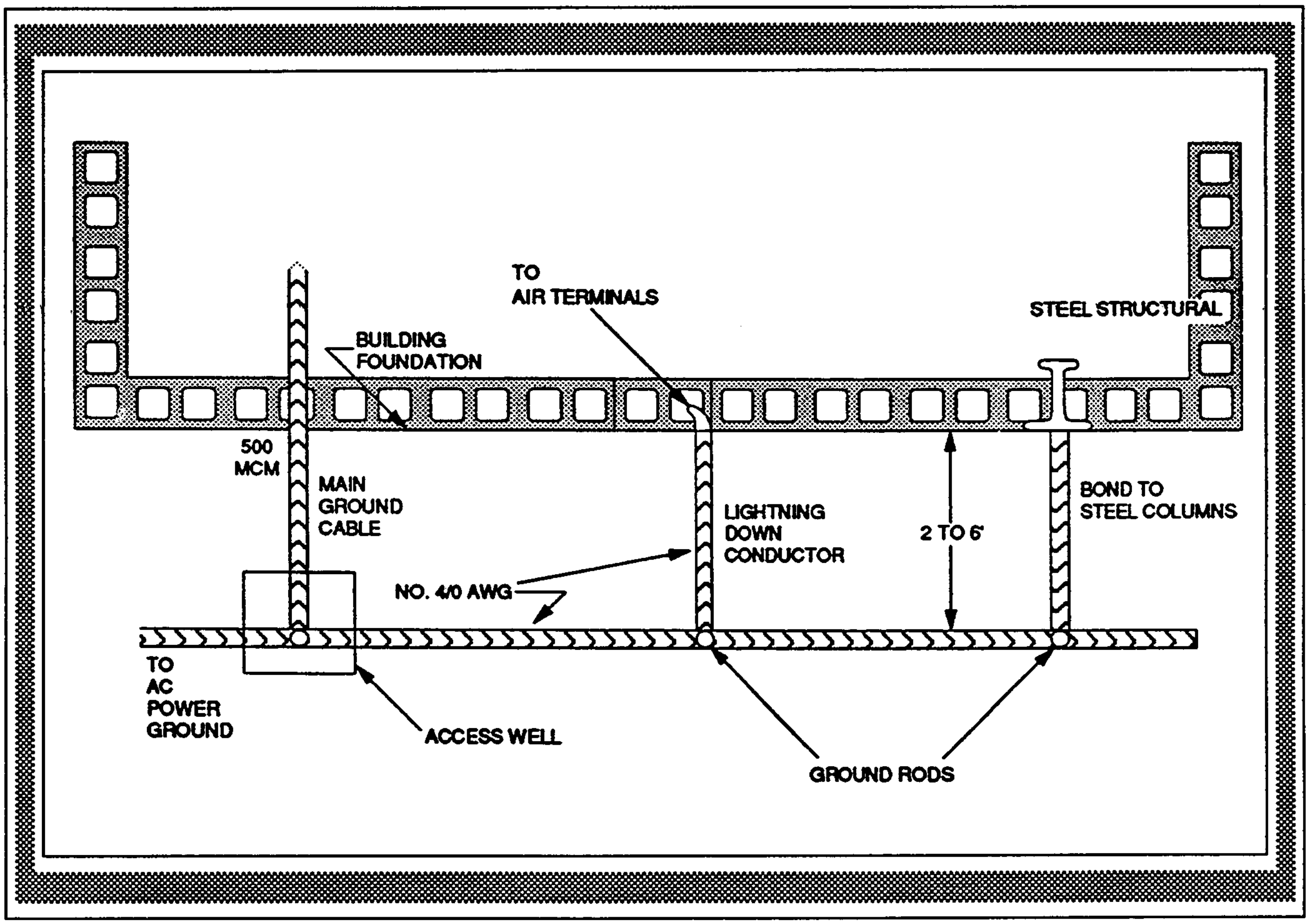
(2) **Earth Electrode System Cables**. The existing earth electrode system cables may be retained if it is found to meet specifications. If the existing earth electrode system cable is smaller than No. 4/0 AWG, bare copper conductor, but meets the test requirements of this directive, the existing interconnecting cable conductor must still be replaced with the proper size components.

e. **Upgrading Existing Earth Electrode System**. The existing earth electrode system shall be upgraded if the average earth resistance reading still exceeds the 10.0 ohms requirement after repairs have been made.

(1) **Existing Interconnecting Conductor**. Any existing bare conductor which does not conform to specifications should be connected to the new earth electrode system to ensure only one grounding system. The existing AC power transformer ground connection may be left intact. Lay a new No. 4/0 AWG bare stranded copper conductor in the trench. Ensure the conductor has no kinks or sharp bends. Attach the new conductor to each ground rod with an exothermic weld using a cross-cable mold and weld material. Cut the No. 4/0 AWG conductor and weld ends together using a No. 4 splicer mold and cartridge.

(2) **Ground Rod Performance**. Two alternatives are available to increase the performance of the ground rod system. At each ground rod, install an additional ground rod on either side and at distances twice the length of the rod. Another approach is to drive the rods deeper into the earth. Sections are added to increase the length as necessary. The method used is determined by soil conditions, site layout, and the results of earth-to-electrode measurements. If the addition of ground rods is not practical, driving them deeper into the earth may reduce the earth-to-electrode resistance to an acceptable level.

<u>**FIGURE 4-9. CONNECTION TO EARTH ELECTRODE SYSTEM**</u>



(3) **Overall Grounding System**. Examine all elements of the facility exterior grounding system from the main ground plate outward. Upgrade the grounding conductors if the conductors are not the proper size. Repair or replace, using exothermic welds, any ground conductor bonds in poor condition. Each air terminal down conductor must be connected directly to a ground rod in the earth electrode grounding system. Install new ground rods as needed for this requirement, and bond each down conductor to its rod with an exothermic weld. Attach each rod to its facility earth electrode grounding system perimeter cable with an exothermic weld or, only in an access well, a clamp.

(4) **Earth Resistance Measurements**. Retest upgraded earth electrode/interconnecting cable system using the procedure described in this chapter, Section 7, Testing.

f. **Alternate Ground Plane System**. Ground plane copper conductor wire size requirements vary with the type and condition of soil encountered or the rock surface they are to cover. In non-corrosive soil the conductors shall be no smaller than No. 6 AWG bare copper wire. A rock surface will require No. 1/0 AWG or larger wire for the conductors. Copper straps three to six inches in width and one-eight inch thick may be used instead of round wire to cover rock surfaces; however, straps shall not be used in high wind areas.

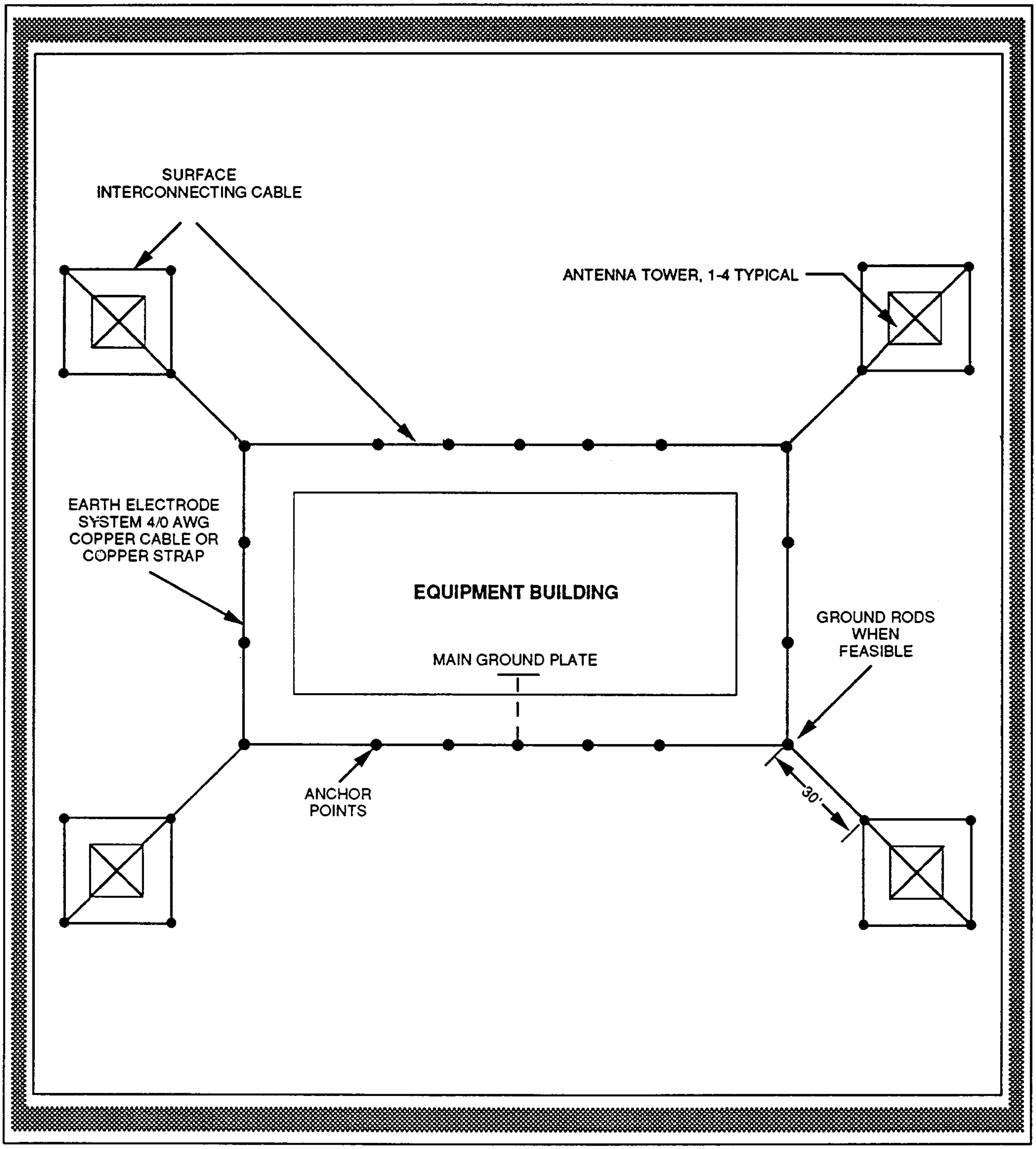
(1) **Soil Installation**. A minimum of three conductors made of copper wires or straps shall be buried at least 24 inches below the surface and extend 20 feet from center. A one piece, copper wire, ground loop surrounds the equipment building and connects the earth electrode ground rods that are driven into the soil around the building. Figure 4-10, Tower and Structure Surface Ground Plane System, shows the position of the earth electrode ground system in a typical poor conducting soil installation.

(a) **Conductor Burial**. Trenches for the conductors are dug either by hand or with a trench digger. Use of ground rods is desirable if soil conditions permit. When ground rods are used they shall always be driven in place. Placement of the individual ground rods is determined by the type of soil and its resistivity.

(b) **Conductor Connection**. Connections are made using exothermic welds or cable clamps. A ground access well is necessary whenever clamps are used to join the individual conductors together.

(c) **Structure Ground Connection**. A structure ground connection is made using a 500 Thousand Circular Mil (MCM) AWG cable attached to an earth electrode system ground rod by an exothermic weld or, within a ground access well, by a cable clamp. The other end of the cable is attached with a bolt lug to the structure ground at the main ground plate. See Paragraph 94, Main Ground Plate Installation.

FIGURE 4-10. TOWER AND STRUCTURE SURFACE GROUND PLANE SYSTEM IN POOR CONDUCTING SOIL



(2) **Rock Surface Installation**. Surface mounted grounds shall slope down and away from the structure being protected. Rock surface installation requires the use of anchor bolts to secure all ground wire or strap to the rock. An anchor bolt shall be used every 10 feet of ground conductor length. No electrical connection is needed from the ground conductor to bolts secured in rock since rock is not a good conductor. Where an area of soil will permit installation of a ground rod, a rod shall be driven into the soil to enhance the ground system. Rod connection to the ground conductor is made with an exothermic weld. Ground rods shall be separated by at least one rod length, but a two rod length minimum separation is preferred. Ground rods are not bunched because mutual inductive coupling reduces their effectiveness as low impedance paths to ground.

(a) **Conductor Placement**. The grounding system elements are placed so that the conductors lie in straight paths which begin at the perimeter of the structure and proceed away from the structure. A ground loop made of No. 4/0 AWG copper is used to connect the individual conductor ends together using exothermic welds at each joint. A typical tower and structure combination using this technique is shown in figure 4-10. When rolling topography, earth berm, or obstacles such as rocks are encountered, the conductor is routed over the obstacle and not around it. The conductors shall not be placed where their paths would encounter large structures or objects which would require them to go around the object. Careful site planning is required when installing an above ground earth electrode system so that enough conductors of the proper length can be used.

(b) **Structure Ground Connection**. The other end of the ground connection cable is connected to the main ground plate inside the structure as in a normal earth electrode counterpoise system installation. A bolt-on lug is used to join the cable to the main ground plate.

g. **Chemical Enhancement**. Ion-producing chemicals are added to the soil surrounding the ground rods. The following chemicals are commonly used for this purpose:

Name	Symbol	Common Name
Magnesium sulfate	$MgSO_4$	Epsom salt
Copper sulfate	$CuSO_4$	Blue vitriol
Calcium chloride	$CaCl_2$	
Sodium chloride	NaCl	Common salt
Potassium nitrate	KNO_3	Saltpeter

Magnesium sulfate is the most commonly used chemical due to its low cost and high electrical conductivity. It is also the least corrosive of the chemicals listed. The chemical can be applied in a trench around the ground rod as shown in Figure 4-11, Trench Method of Soil Treatment, or in an access well like the one shown in Figure 4-12, Alternate Method Of Soil Treatment.

h. **Documentation of Earth Electrode System Installation**. Redline all applicable facility drawings to indicate any changes to the existing drawing details caused by any updating of the existing earth electrode system. Changes to the new drawings for a new earth electrode system shall also be made. Photographs of below ground exothermic welds should be taken. All applicable documentation is to be conveyed to facility management.

i. **Materials Required**. Installing, repairing, or upgrading the earth electrode system may require any or all of the materials listed in Table 4-1, RCF Earth Electrode System Installation Materials.

93. **MAIN GROUND PLATE**. The main ground plate provides a central connection point from the internal grounding system to the external earth electrode system components.

94. **MAIN GROUND PLATE INSTALLATION.**

a. **Main Ground Plate**. The main ground plate shall be installed on an interior wall or floor of the facility equipment shelter. The main ground plate is a 4 inch by 12 inch by 1/4 inch copper plate mounted on nonconductive material and secured with insulated hardware. The plate shall be mounted as close as possible to where the connection is made to the earth electrode system.

b. **Exterior PVC Conduit**. Install a section of Polyvinyl Chloride (PVC) conduit through the facility exterior wall between the main ground plate junction box and the PVC junction (LB fitting) outside of the facility wall as illustrated in Figure 4-13, Main Ground Plate Installation. Install PVC conduit and a PVC sweep elbow between the PVC junction and the ground access well. Attach the PVC conduit to the facility wall with straps. An earth electrode system ground rod at the access well shall be dedicated to the main ground plate and be in the vicinity of the PVC sweep elbow.

c. **Main Ground Conductor**. Install an AWG No. 500 MCM size insulated copper conductor between the main ground plate and the earth electrode system ground rod at the ground access well. If a ground rod does not exist in the earth electrode system near the PVC sweep elbow, install a ground rod and access well dedicated to the main ground plate. Then attach it to the earth electrode ground system. Refer to Table 4-2, New Installation Junction Box, Main Ground Plate.

FIGURE 4-11. TRENCH METHOD OF SOIL TREATMENT

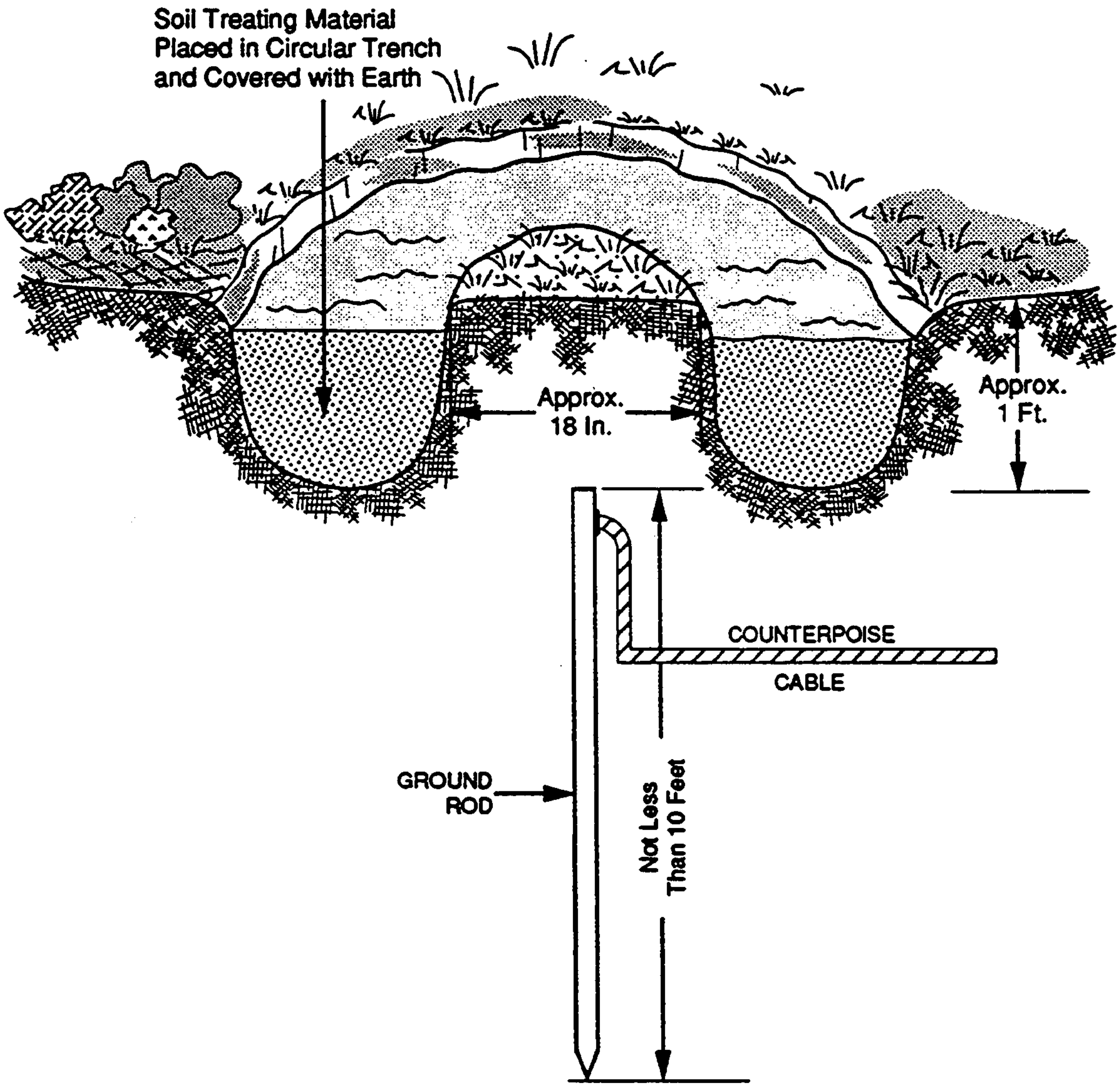


FIGURE 4-12. ALTERNATE METHOD OF SOIL TREATMENT

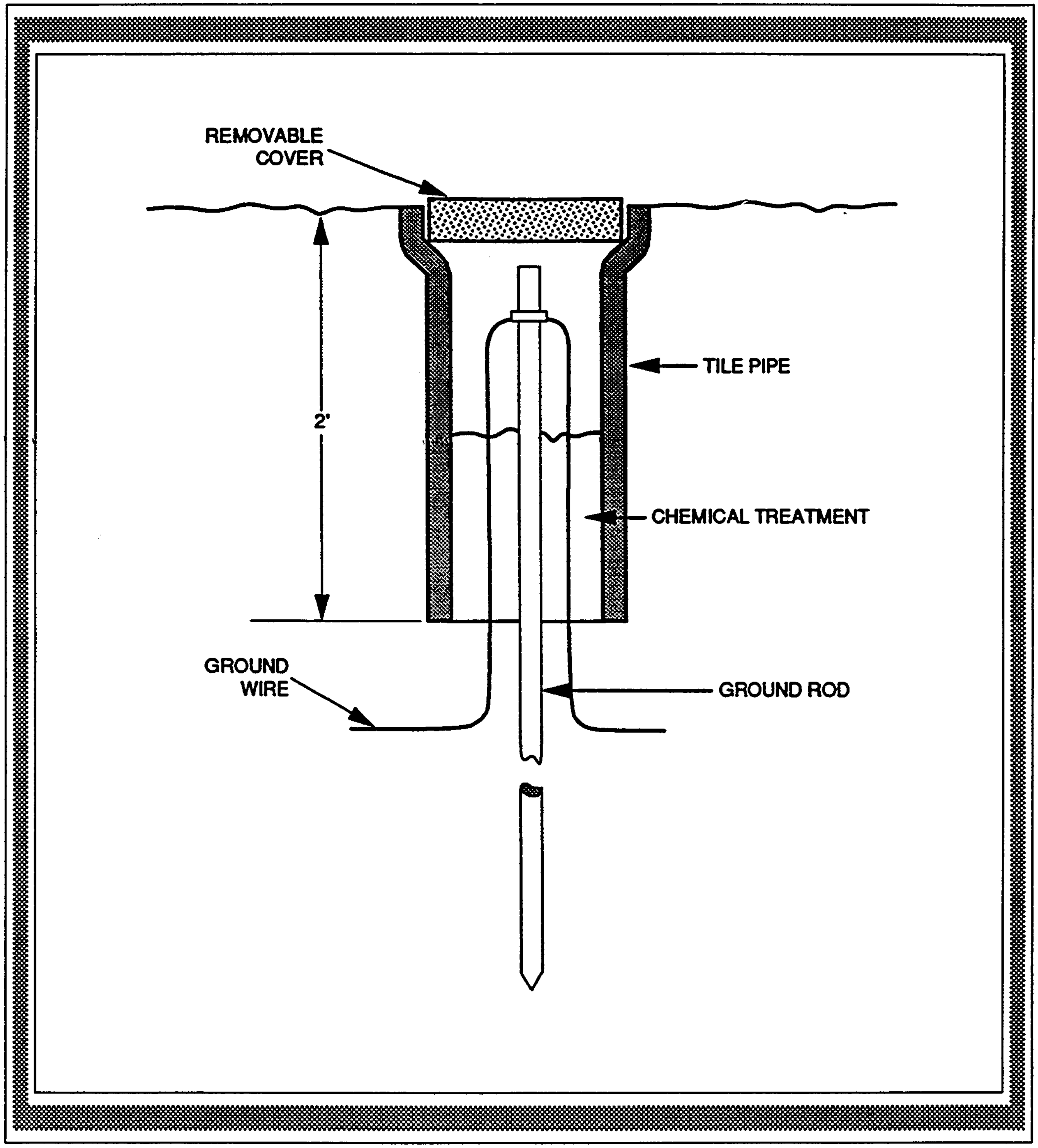


TABLE 4-1. RCF EARTH ELECTRODE SYSTEM INSTALLATION MATERIALS

ITEM	DESCRIPTION	QUANTITY
1.	Ground rod, sectional, copper clad steel, 3/4 inch x 10-feet, IPC No. 579T, or equal	As Required
2.	Ground rod, solid copper clad steel, threaded coupler, IPC No. 141Y, or equal	As Required
3.	Driving stud, IPC No. 141F, or equal	As Required
4.	4/0 AWG stranded bare copper conductor, 19 strand, Alpha No. 7388, or equal	As Required
5.	Welding mold, 3/4 inch ground rod to 4/0 AWG cross-cable, Cadweld GYE-182Q, or equal	As Required
6.	Weld metal , Cadweld #150, or equal	As Required
7.	Weld metal, Cadweld #2-200, or equal	As Required
8.	Splicer mold, 4/0 AWG size cable splicer, Cadweld HDSSC-2Q, or equal	As Required
9.	Ground rod splice mold, 3/4" copper rod Cadweld HDGBD-18, or equal	As Required
10.	Handle clamps, Cadweld L-160, or equal	As Required

FIGURE 4-13. MAIN GROUND PLATE INSTALLATION

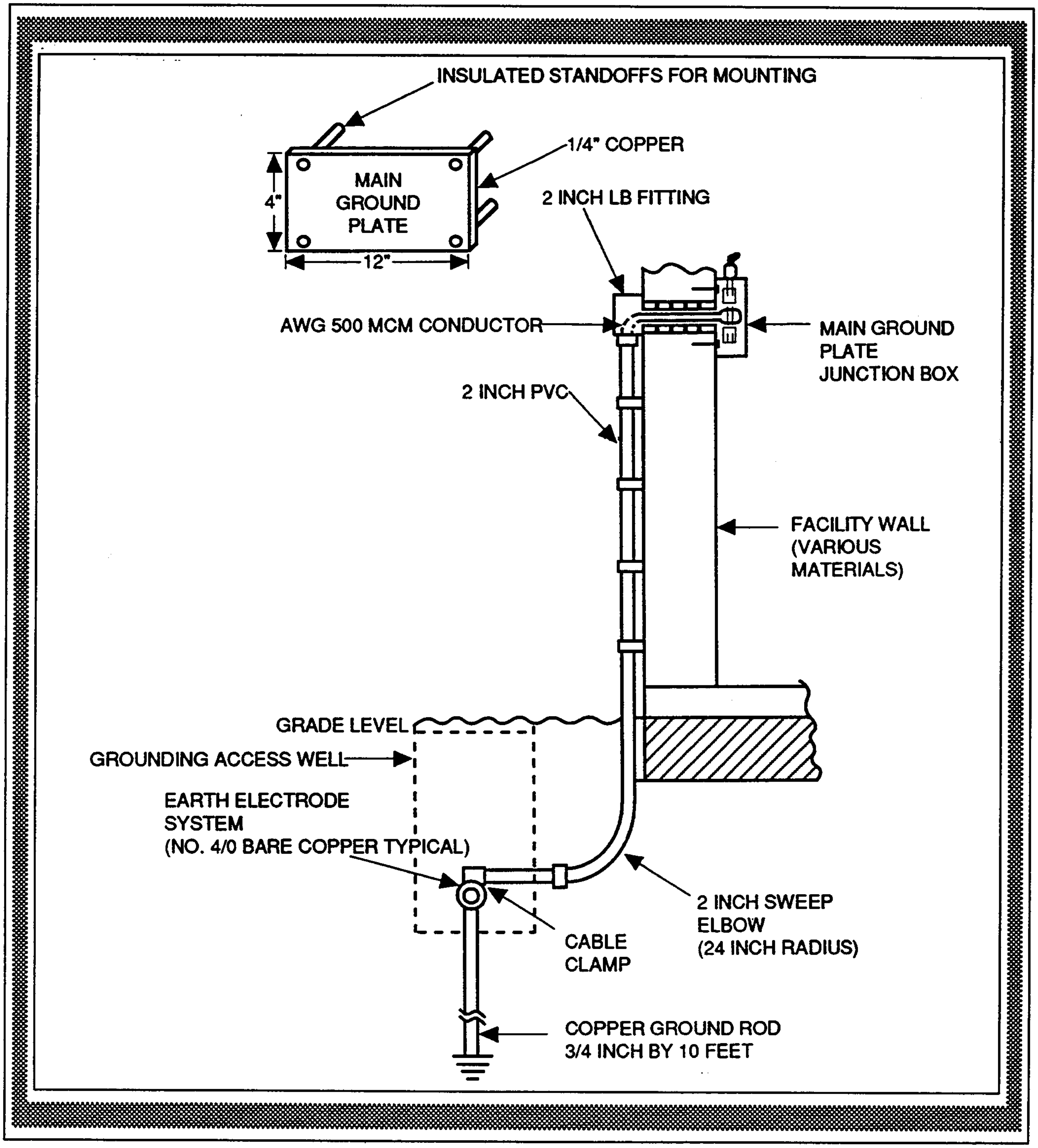


TABLE 4-2. NEW INSTALLATION JUNCTION BOX, MAIN GROUND PLATE

ITEM	DESCRIPTION	QUANTITY
1.	Junction Box, PA-16, per FAA Drawing DK-6075-19	1 each
2.	Connector, compression type, 1-1/2inch steel, Thomas & Betts 5523 or equal	2 each
3.	Conduit, thin-wall, 1-1/2 inch galvanized steel	As Required
4.	Wall Anchors with screws (depends on wall construction material)	4 each
5.	No. 6 AWG, (green with orange tracer), stranded, insulated copper wire	As Required
6.	Lug, screw, Thomas & Betts 35301 or equal	1 each
7.	Connector, split-bolt, Burndy Type KS17, or equal	1 each
8.	Connector, split-bolt, Burndy Type KS22, or equal	1 each
9.	Connector, split-bolt, Burndy SERVIT Post Type K2C22, or equal	As Required
10.	Compound, sealing, Chico A3, or equal	1 lb
11.	Tie wrap, nylon,	As Required

In new installations, the cable should come up from a conduit provided in the building foundation since the main ground conductor can be difficult to bend in some cases.

95.-98. **RESERVED**.

SECTION 3. LIGHTNING PROTECTION SYSTEM

99. **REQUIREMENTS**. Equipment and structure damage from lightning comes in two forms: a direct lightning discharge to the equipment or structure, and a surge in voltage and current on electrical connections to the equipment. The RCF facility shall be protected from both occurrences. There are three basic elements for a lightning protection system. These elements are an electrically conductive object, an electrically conductive path, and a low-resistance electrical connection with the earth. Protection conditions are satisfied when a lightning discharge is routed to the earth through a conductive path which prevents damage to the facility or equipment it is designed to protect.

a. **Electrically Conductive Object**. The conductive object shall be an air terminal mounted at the highest elevation of the part of a structure, or its equipment, to be protected. Air terminals shall be solid copper, bronze, or aluminum rods 10 inches long minimum with a rounded point. Copper rods may be nickel plated. Copper or bronze rods shall be 1/2 inch in diameter and aluminum rods 5/8 inch in diameter. Required locations of air terminals are determined by the zone of protection provided by each air terminal, beginning with the highest in elevation. Figure 4-14, Lightning Protection for Antenna Platforms, shows a protected antenna and tower. A zone of protection is the concave area between a structure and a ball of lightning, of 100 to 150 foot radius, as the ball rolls up to, over, and down mounted air terminals. Zones designed with a 150 foot radius ball would protect against most discharges from common 150 foot stepped lightning leaders. See maximum protection zones using 100 foot radii in Figure 4-15, Determining Air Terminals for Buildings Under 50 Feet Tall; Figure 4-16, Determining Air Terminals for Towers; and Figure 4-17, Air Terminal Protection of Flat Surfaces. Refer to FAA-STD-019b and National Fire Protection Association Code NFPA-780 also.

b. **Electrically Conductive Path**. Multiple air terminals on a structure shall be interconnected by a perimeter cable to provide at least two paths to ground from each air terminal. A down conductor connects one or more air terminals to the earth electrode system.

c. **Earth Connection**. An exothermic weld or cable clamp shall connect the earth electrode system to a ground conductor providing the earth connection.

FIGURE 4-14. LIGHTNING PROTECTION FOR ANTENNA PLATFORMS

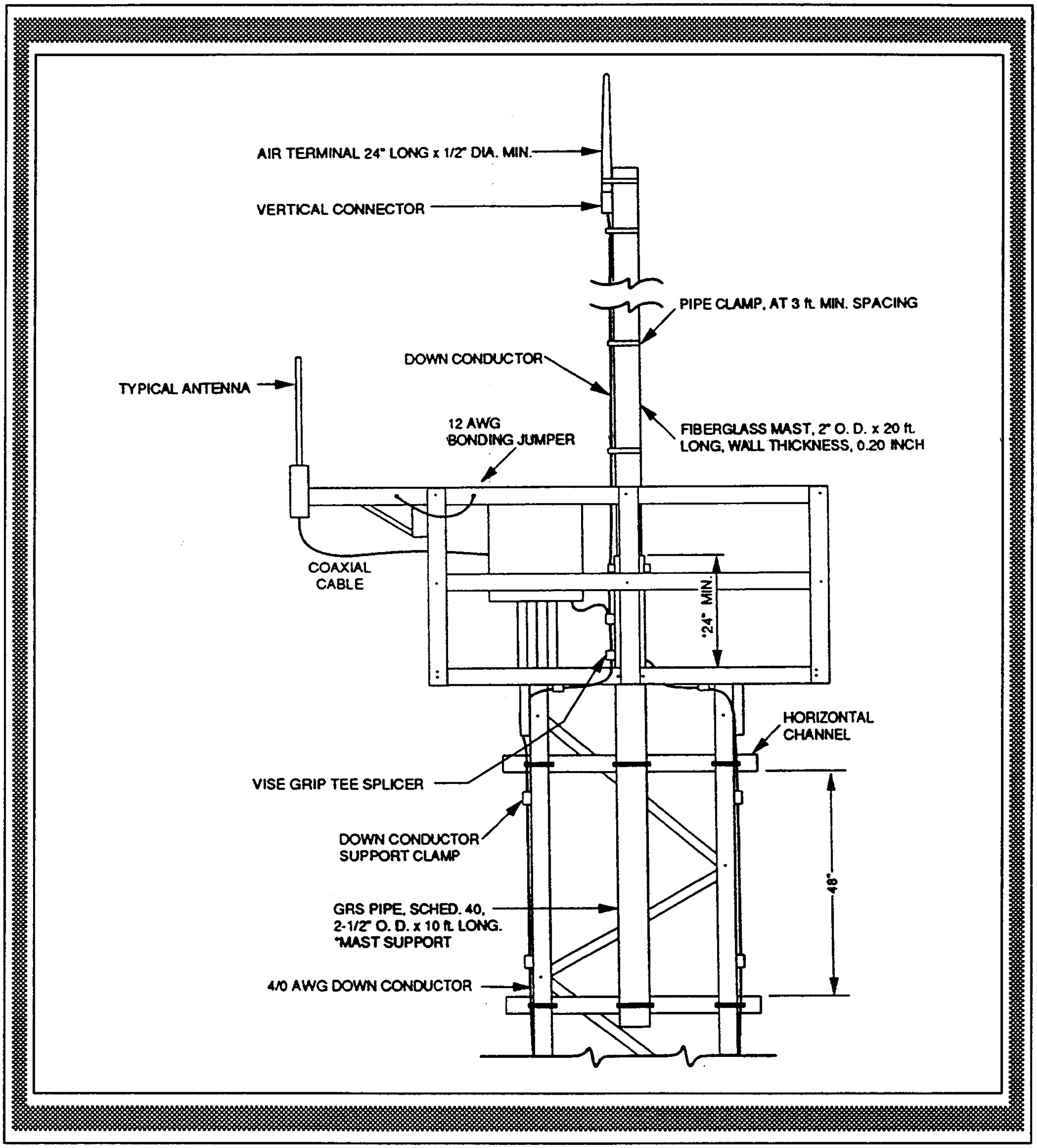


FIGURE 4-15. DETERMINING AIR TERMINALS FOR BUILDINGS UNDER 50 FEET TALL

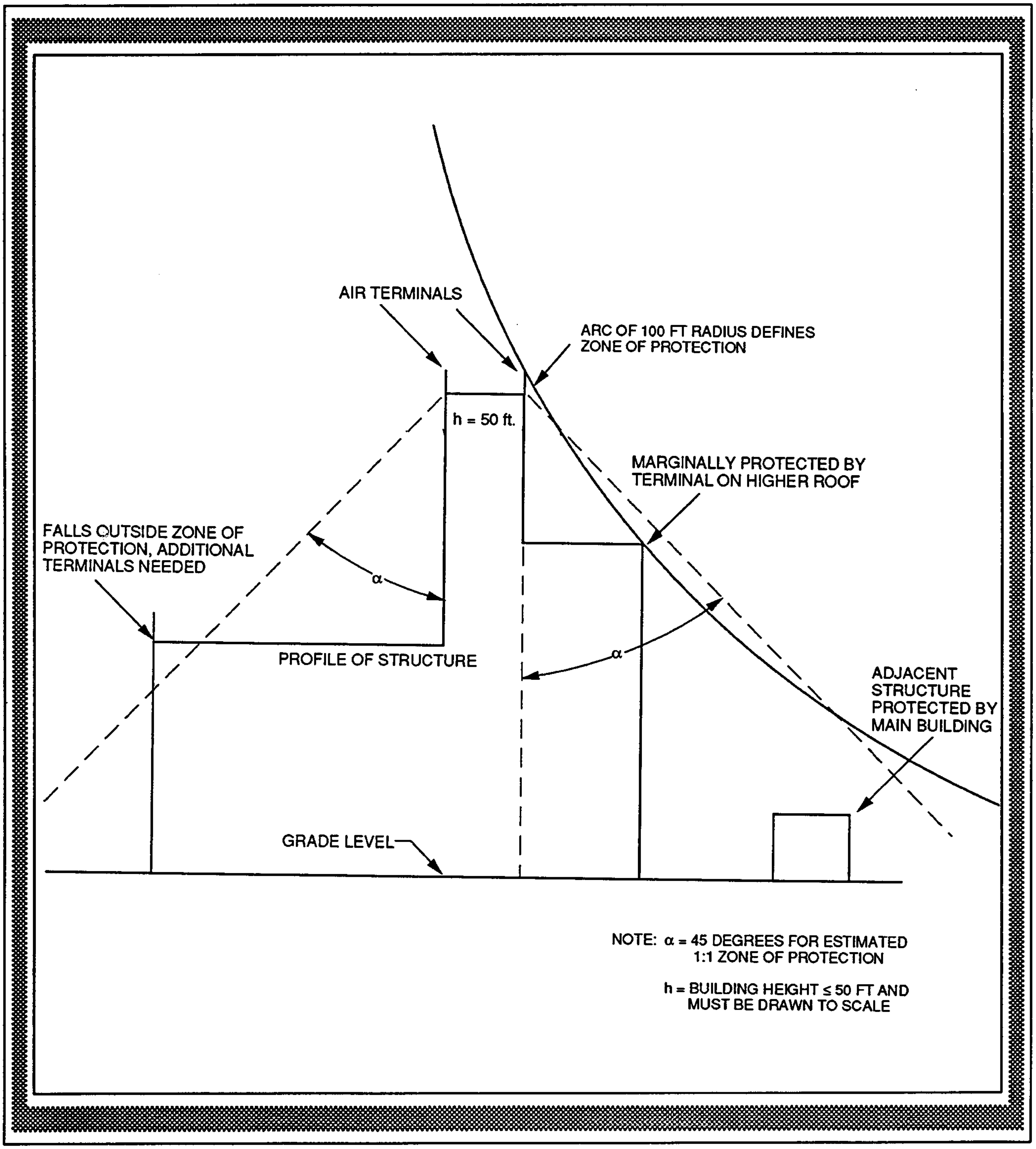
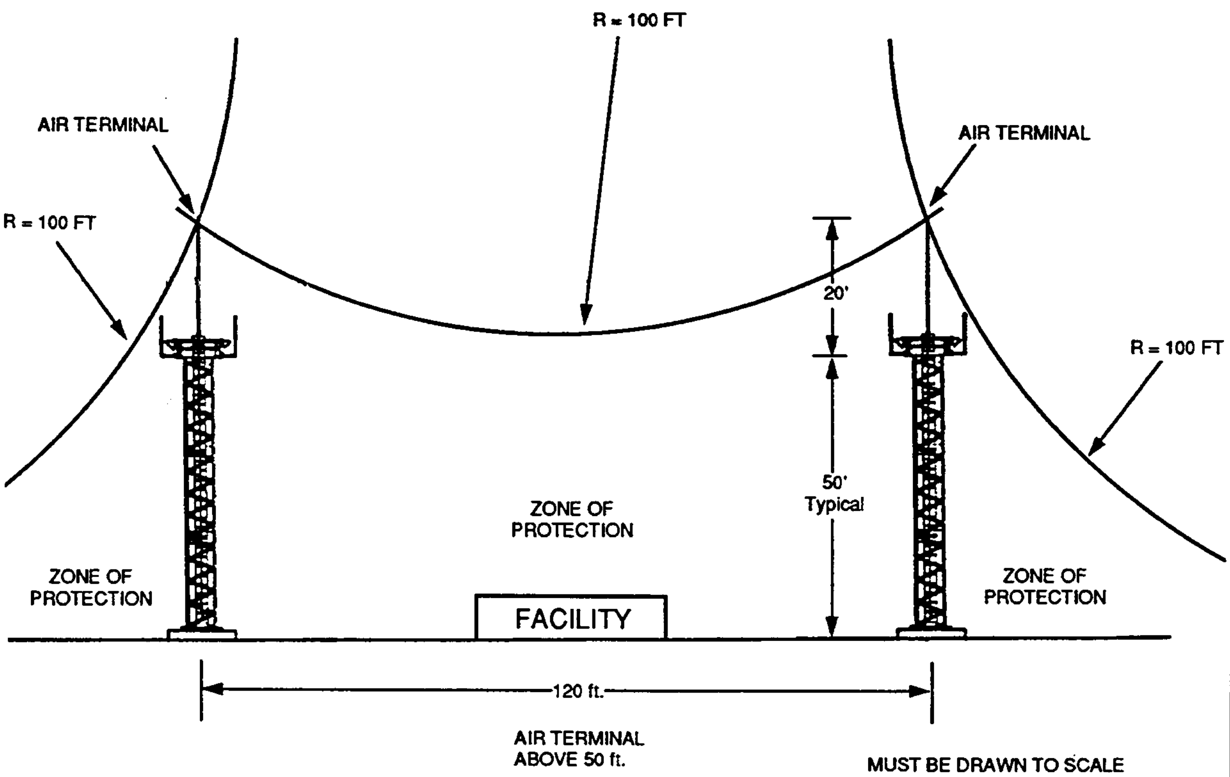
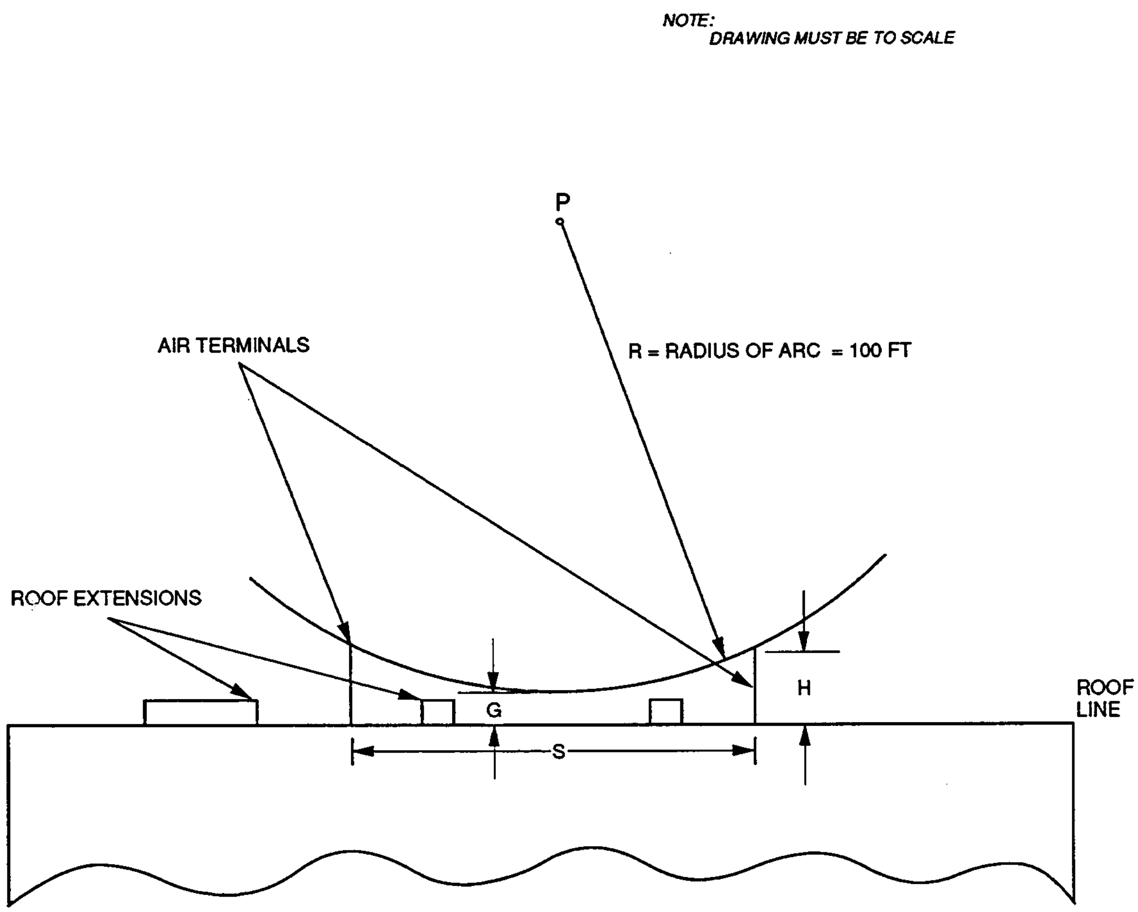


FIGURE 4-16. DETERMINING AIR TERMINALS FOR TOWERS



NOTE: P IS THE CENTER, AND R THE RADIUS, OF A CIRCLE TOUCHING THE EARTH AND THE TOP OF AN AIR TERMINAL. EACH ARC DEFINES THE ZONE OF PROTECTION FOR ONE TOWER ANTENNA. THE INTERSECTION OF TWO ARCS AS SHOWN DEFINES THE ZONE OF PROTECTION BETWEEN THE TOWERS.

FIGURE 4-17. AIR TERMINAL PROTECTION ON FLAT SURFACES



DETERMINATION EQUATION:

$G = H - R + \sqrt{R^2 - (\frac{S}{2})^2}$

IF $G = 0$

$S_{max} = 2\sqrt{H(2R - H)}$

$H_{min} = R - \sqrt{R^2 - (\frac{S}{2})^2}$

LEGEND

P = POINT OF DISCHARGE FROM FINAL STEPPED LIGHTNING LEADER (CENTER OF ARC)

H = HEIGHT OF TERMINAL

G = MINIMUM ELEVATION COMPLETELY PROTECTED

S = SPACING BETWEEN TERMINALS

100. **INSTALLATION**. An air terminal shall extend at least 10 inches above the highest point it is protecting. Air terminals over 24 inches long shall be braced at mid point. Bimetallic connectors shall be used for connecting dissimilar metals such as aluminum and copper or copper and steel. A zone of lightning protection for each structure or group of structures at a site shall conform to FAA-STD-019b and Lightning Protection Code, NFPA-780. Use of 100 foot radius arcs in determining zones of protection provides maximum protection.

a. **Tower Protection**. An air terminal system shall be used to protect towers from lightning damage. All antennas must be within the tower's zone of protection. The air terminal grounding system and its tower grounding systems shall be installed under the same guidelines and required standards as the earth electrode system. Two down conductors, routed down separate tower legs where possible and away from RF cables, shall connect the tower grounding system to the structure earth electrode system.

(1) **Self-Support Towers**. A self supported tower requires one or more air terminals and two down conductors as part of its lightning protection system. Air terminals shall be interconnected by Thompson No. 506 cable, or equal, to provide two separate grounding paths from the tower grounding system via down conductors as shown in Figure 4-18, Antenna Tower Grounding and Lightning Protection. A metal tower whose own structure provides a continuous straight downward electrical path may be considered a part of, but not a replacement for, the down conductor clamped to it. A tower base plate shall be connected to the structure and grounded to its nearest down conductor, keeping the path in air for the cable as short as possible. Each down conductor shall take a straight downward path, with no sharp bends, to a bonding plate near the ground before entering PVC to reach a grounding rod. Each down conductor shall be connected by exothermic weld to a corner ground rod in the structure earth electrode system.

(2) **Guyed Towers**. Guyed towers have the same grounding and lightning protection requirements as a self supported tower. Guy wires and anchors used in the installation of guyed towers shall be grounded also, unless the guy wires are insulated. Guy wires shall be grounded near the turn buckles using wire or strap of the same metal as the guy wires unless bimetallic connectors are used to isolate dissimilar metals. To avoid sharp bends and wire tension, the grounding wire shall follow a downward curving stepped path as shown in Figure 4-19, Guyed Tower Grounding and Lightning Protection.

FIGURE 4-18a. ANTENNA TOWER GROUNDING AND LIGHTNING PROTECTION

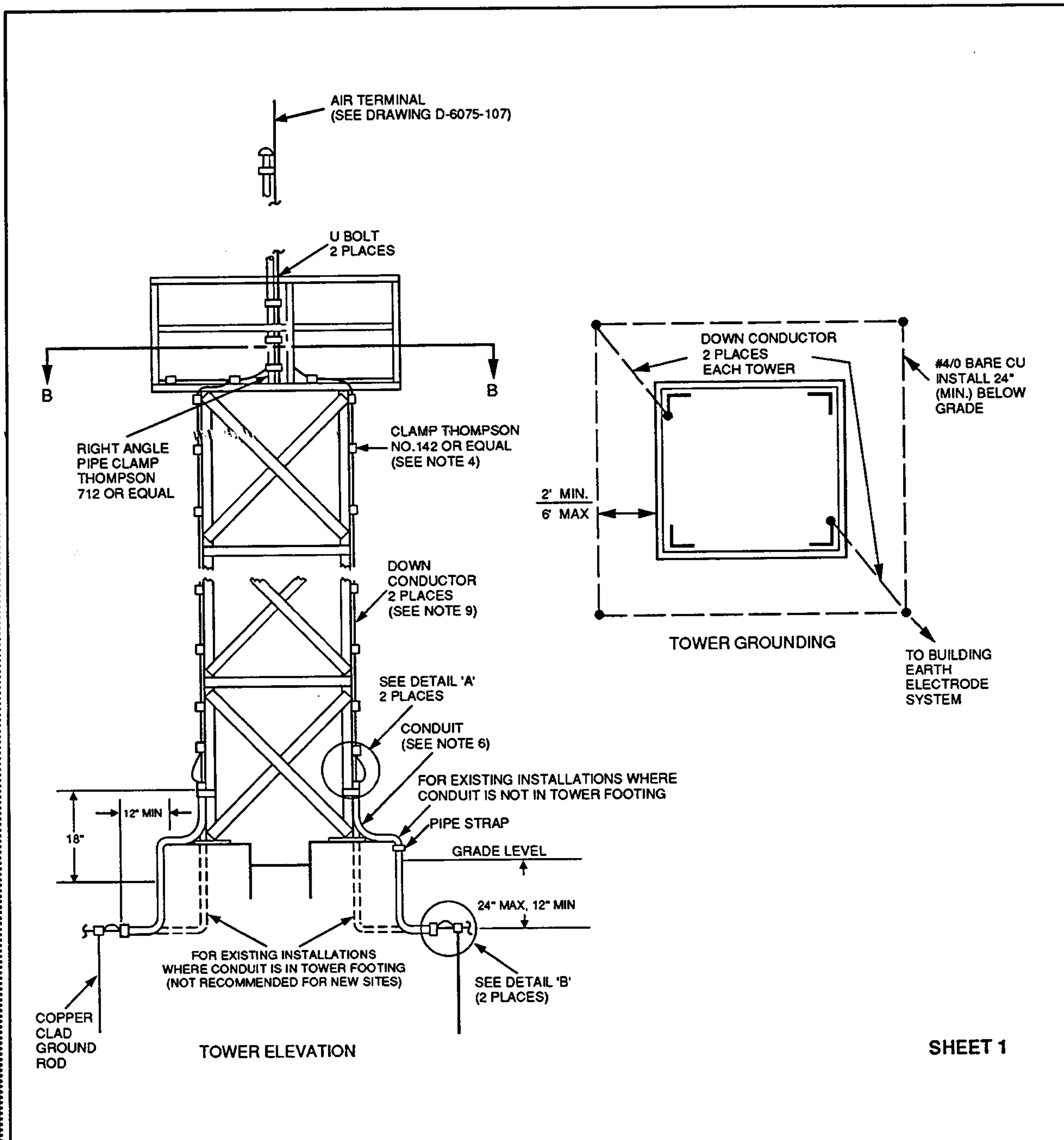
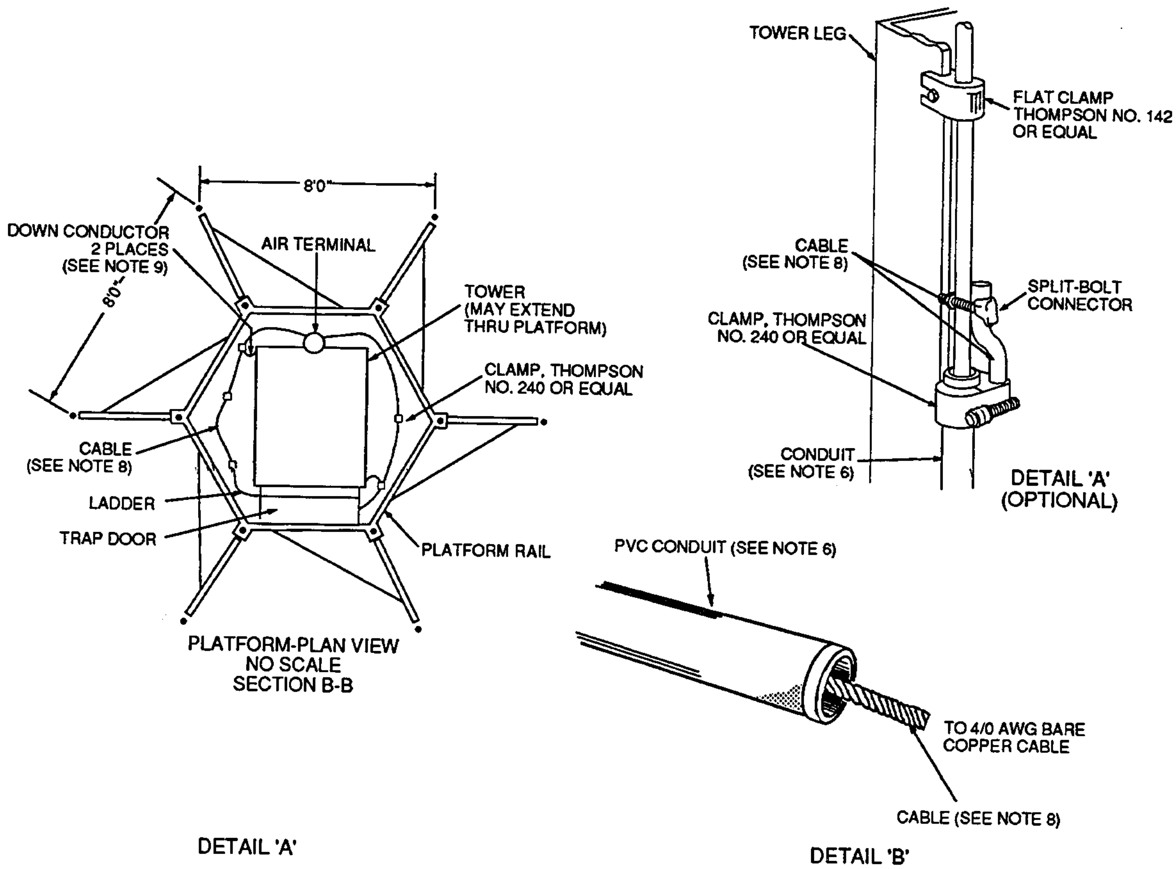


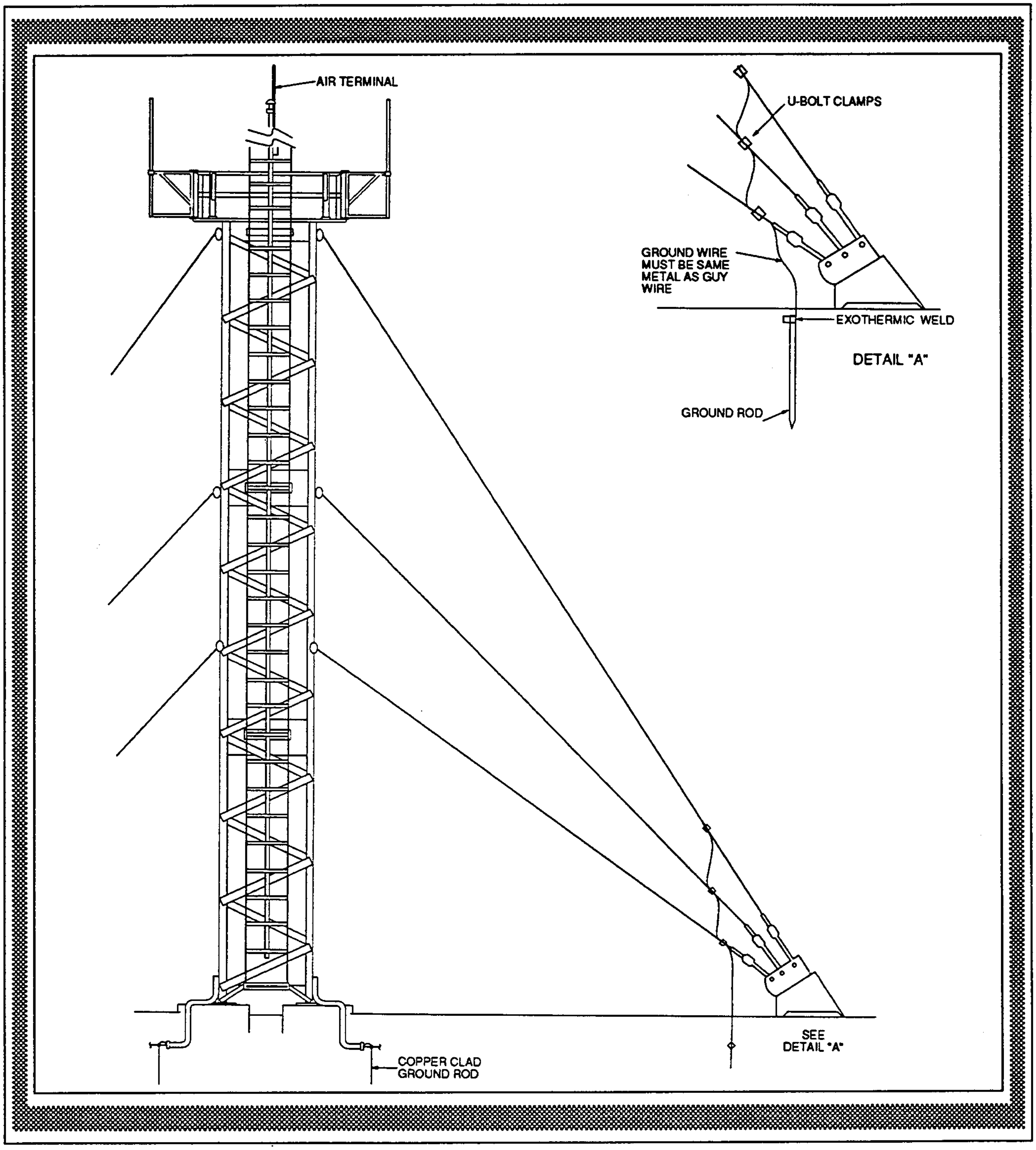
FIGURE 4-18b. ANTENNA TOWER GROUNDING AND LIGHTNING PROTECTION



1. CONDUIT AND DOWN CONDUCTOR BEND RADIUS 8" MIN.
2. CONDUIT AND DOWN CONDUCTOR BEND ANGLE 90°
3. EXTEND CABLES 1" BEYOND TERMINATING CONNECTIONS AND FITTINGS.
4. DISTANCE BETWEEN CLAMPS ATTACHING CONDUCTORS TO TOWER SHALL BE 36" MAX.
5. CLEAN BONDING SURFACES UNDER CLAMPS TO BARE METAL, SECURE HARDWARE AND WATERPROOF WITH SILICONE SEALING COMPOUND.
6. FOR CONDUIT REPLACEMENT OR NEW CONSTRUCTION USE SCHEDULE 40 PVC CONDUIT AND OMIT BONDING JUMPER AND FITTINGS. ROUTE CONDUIT THROUGH CONCRETE FOOTING FOR NEW CONSTRUCTION.
7. INSTALL BURIED CABLE 2 FEET BELOW GRADE AND 2 TO 5 FEET FROM TOWER BASE.
8. ALL TOWERS USE THOMPSON NO. 506 CABLE OR EQUAL.
9. INSTALL TWO DOWN CONDUCTORS ON THREE AND FOUR LEG TOWERS. ROUTE CONDUCTORS DOWN OPPOSITE LEGS OF FOUR LEG TOWERS. DO NOT ROUTE DOWN CONDUCTORS WITH ELECTRICAL CABLES.
10. BOND OBSTRUCTION LIGHT CONDUIT AND ANTENNA SUPPORTS TO DOWN CONDUCTORS USING CLAMPS, BONDING JUMPER AND FITTINGS.
11. INSTALL LONGER GROUND RODS OR ADDITIONAL GROUND ROD SECTIONS WHEN NECESSARY TO REDUCE RESISTANCE OR EXTEND RODS INTO PERMANENT MOISTURE BEARING SOILS.
12. CONNECT THE ELECTRODE GROUNDING SYSTEM SHOWN TO THE EQUIPMENT BUILDING GROUNDING SYSTEM USING BARE NO. 4/0 AWG COPPER CABLE BURIED 2' BELOW GRADE AND EXOTHERMIC WELD OR EQUAL CONNECTIONS.
13. WHERE EXISTING TOWERS ARE INDIVIDUALLY GROUNDED AND GROUND RESISTANCE IS SATISFACTORY (APPROX.10 OHMS) THE BURIED 4/0 AWG COPPER CABLE INTERCONNECTING TOWERS AND THE GROUND RODS BETWEEN TOWERS ARE NOT REQUIRED.
14. MISCELLANEOUS HARDWARE SHALL BE COPPER, BRONZE OR STAINLESS STEEL.

SHEET 2

FIGURE 4-19. GUYED TOWER GROUNDING AND LIGHTNING PROTECTION



b. **Structure Protection**. Two or more down conductors shall be provided for building structures with a perimeter of 250 feet or less. The down conductors shall be No. 4/0 AWG copper cable. Structures whose perimeter exceeds 250 feet shall use one down conductor for every 100 feet of perimeter distance.

c. **Transmission Line Shield Grounding**. Shields on antenna RF coaxial cables shall be grounded to the earth electrode system in the tower junction box and at the entrance to a facility. Transient suppressors are provided at the facility entrance. Coaxial cable bus grounding at the tower is illustrated in Figure 4-20, Typical Tower Coaxial Cable and Junction Box Grounding. At some sites an external bulkhead plate may be the facility coaxial cable grounding point. A No. 2/0 AWG copper wire shall be attached to this copper plate with a bolt lug and be routed to the facility earth electrode system. Figure 4-21, Typical Coaxial Cable Bulkhead Plate, shows this ground cable. At other facilities conduits may be used to bring the antenna coaxial cables into the building to a cable junction or patch panel box. In either case, the cable outer shield and connectors shall be grounded to the facility earth electrode system. A No. 2/0 AWG copper wire routed to the facility earth electrode system shall be attached with a bolt lug to the copper bar or plate which grounds coaxial cable outer shielding. Figure 4-22, Typical Cable Grounding in Antenna Patch Panel, contains facility entrance feedthrough transient suppressors and illustrates RF coaxial cable transient protection bus grounding.

d. **Protection of Underground Cables**. Buried AC power lines and signal and control landlines, except RF coaxial cables, are protected best in grounded electrically continuous watertight ferrous conduit. Runs more than 300 feet, except AC power lines, may use armored cable. Protection against direct lightning strikes to buried cables not completely enclosed in ferrous metal conduit shall be provided by installing a guard wire At least 10 inches above and parallel to the buries cables. No. 6 AWG bare copper wire is recommended for guard wire as shown in Figure 4-23, Lightning Protection for Underground Cables. For a spread of cables 3 feet wide or less, only one guard wire is necessary. For wider cable spreads, at least two guard wires shall be installed. All guard wires shall be connected to the earth electrode system. Buried cables must enter a facility in ferrous conduit. The conduit must extend a minimum of 5 feet beyond the earth electrode system with the outer end bonded to the earth electrode system with a stranded bare copper conductor, No. 2/0 AWG minimum. The facility end of conduit shall be bonded to the entrance housing.

101.-105. **RESERVED**.

FIGURE 4-20a. TYPICAL TOWER COAXIAL CABLE AND JUNCTION BOX GROUNDING

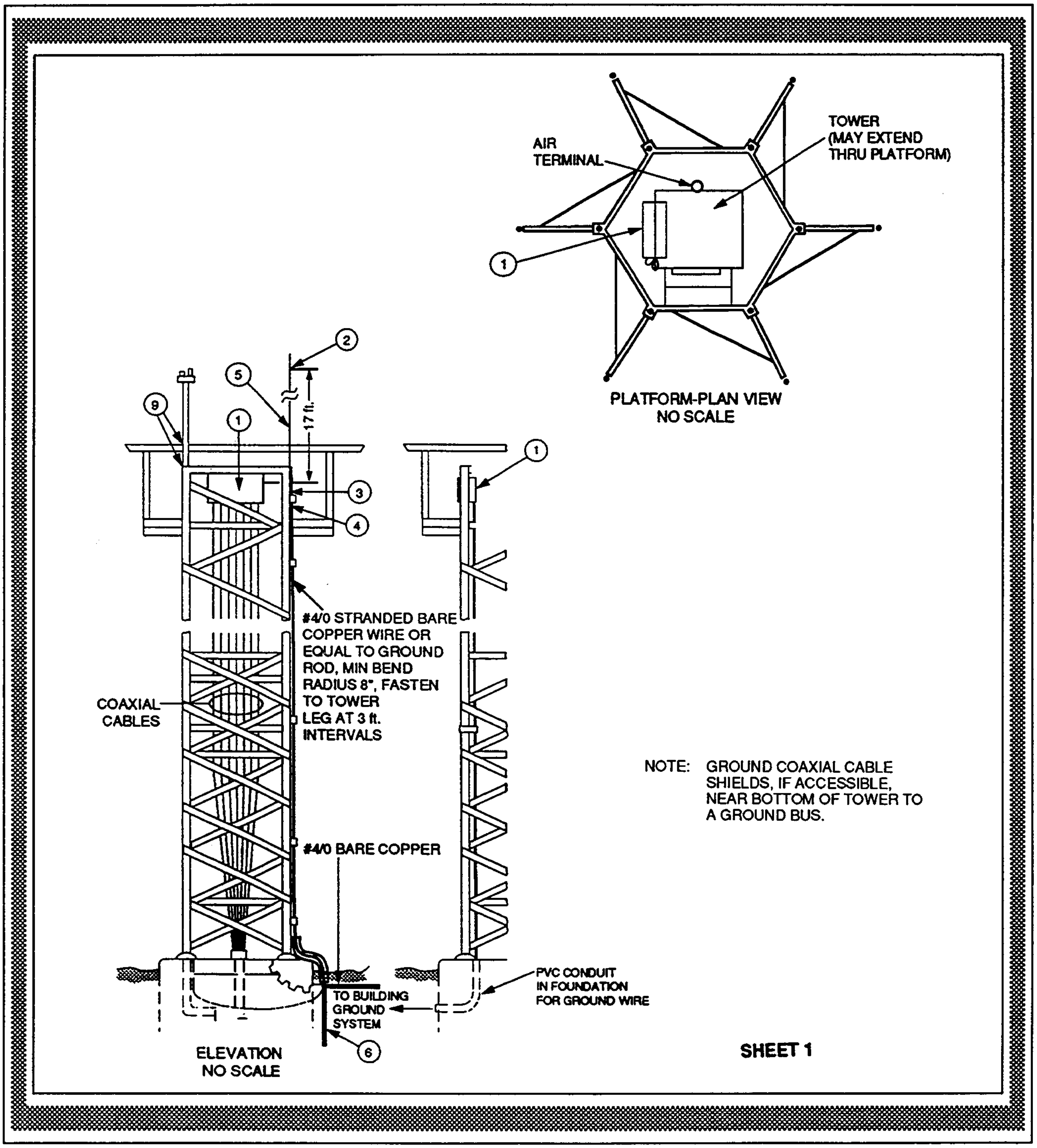
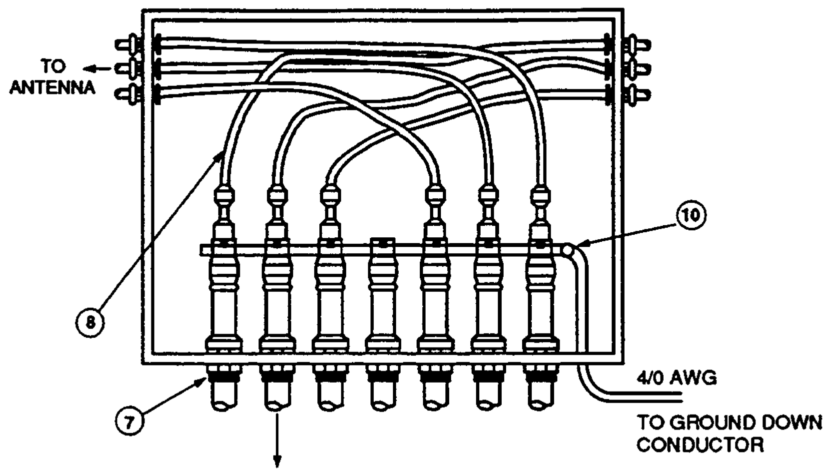


FIGURE 4-20b. TYPICAL TOWER COAXIAL CABLE AND JUNCTION BOX GROUNDING

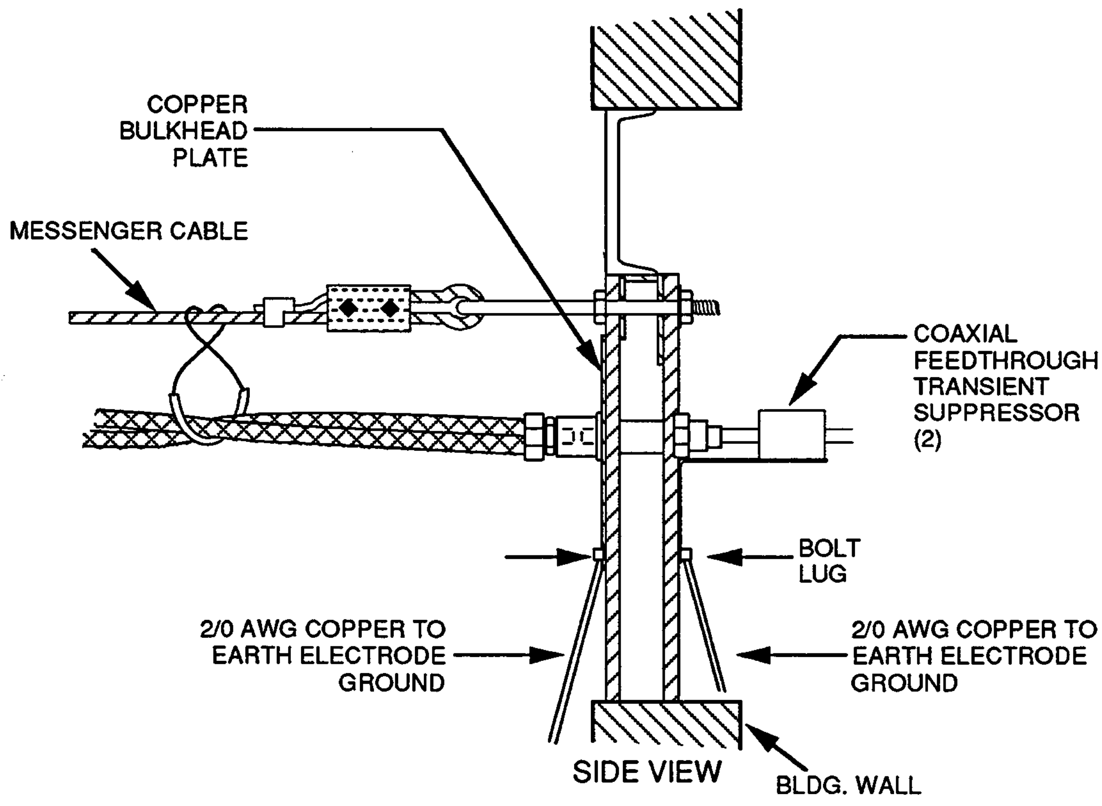


NOTES:

1. 24" x 20" x 6" DEEP WATERTIGHT JUNCTION BOX NEMA 12 (CIRCLE AW OR EQUAL). BOX TO BE SECURELY BOLTED TO TOP RAIL AND TO GALV.ANGLE IRONS.
2. AIR TERMINAL INSTALLATION IN THE CENTER OF THE TOWER. GROUNDING AND INSTALLATION OF THE LIGHTNING ROD SHALL BE IN ACCORDANCE WITH FAA STANDARD DRAWING SERIES FAA-D-6075.
3. COPPER U-BOLT CLAMP (NO. 182, INDEPENDENT PROTECTION CO., OR APPROVED EQUAL).
4. 5/8" BRONZE SUPPORT BRACKET (NO. 67X. INDEPENDENT PROTECTION CO., OR APPROVED EQUAL.
5. 5/8"x8" COPPERWELD GROUND ROD THREADED TO MATCH LIGHTNING ROD TIP AND BASIC BRACKET.
6. 3/4"x 10" COPPERCLAD GROUND ROD TIES TO ANTENNA GROUND AND BUILDING GROUND WITH A NO. 2 BARE COPPER WIRE.
7. CONNECTOR, WATERTIGHT WITH LOCKNUT (TYPE T & B 2558 OR EQUAL)
8. BRING CABLES INTO PATCH BOX. LEAVE 2 FEET OF EXCESS-CABLE AND MAKE ENDS WATERTIGHT WITH TAPE.
9. ANTENNA TOWER, SAFETY RAIL, PLATFORM, AND COAXIAL CABLE ARE GOVERNMENT FURNISHED. ALL OTHER ITEMS SHOWN ARE CONTRACTOR FURNISHED.
10. COPPER GROUNDING BAR WITH LUG (SPECIAL TO SITE)

SHEET 2

FIGURE 4-21. TYPICAL COAXIAL CABLE BULKHEAD PLATE



NOTE: BULKHEAD PLATE ILLUSTRATION USED IF APPLICABLE

FIGURE 4-22. TYPICAL CABLE GROUNDING IN ANTENNA PATCH PANEL

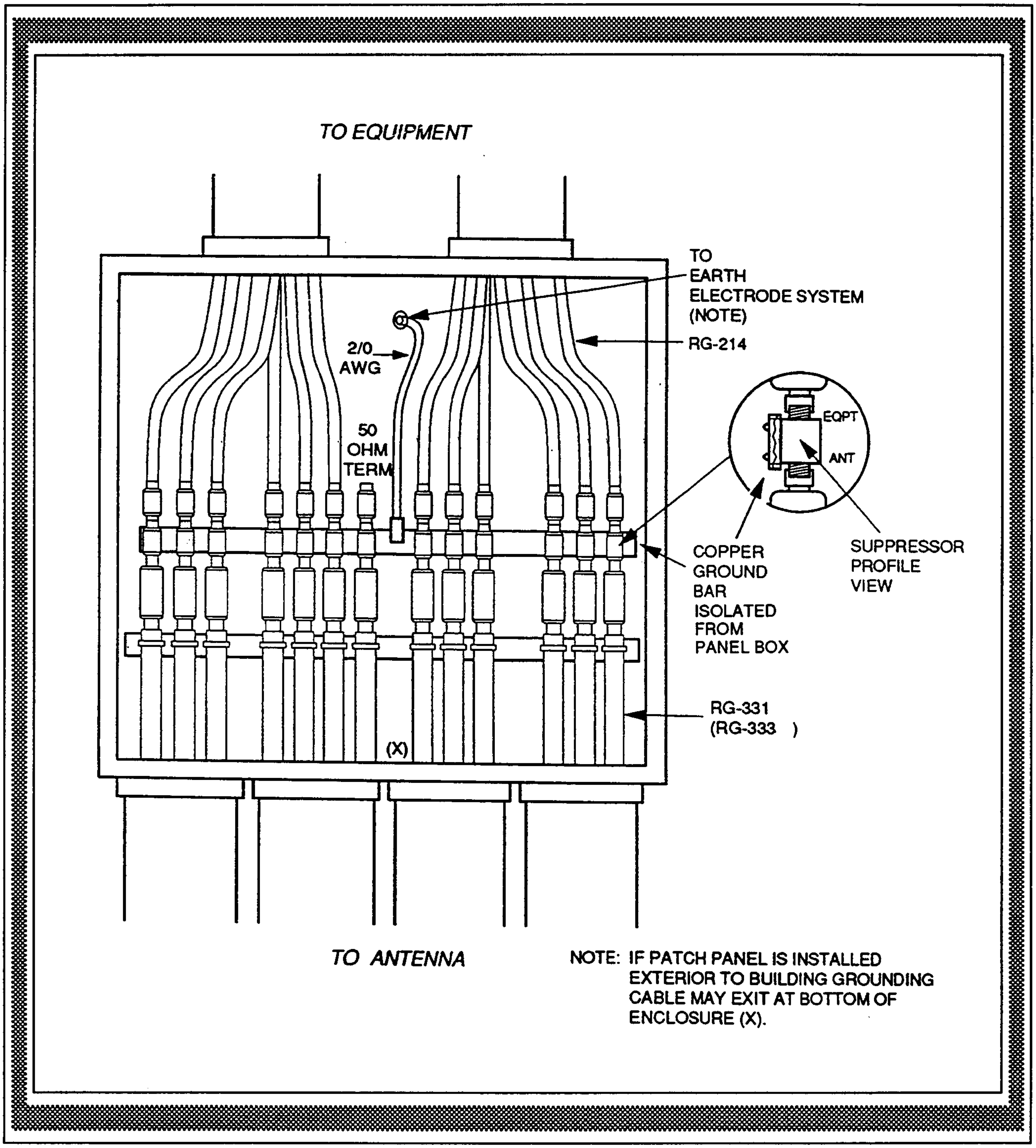
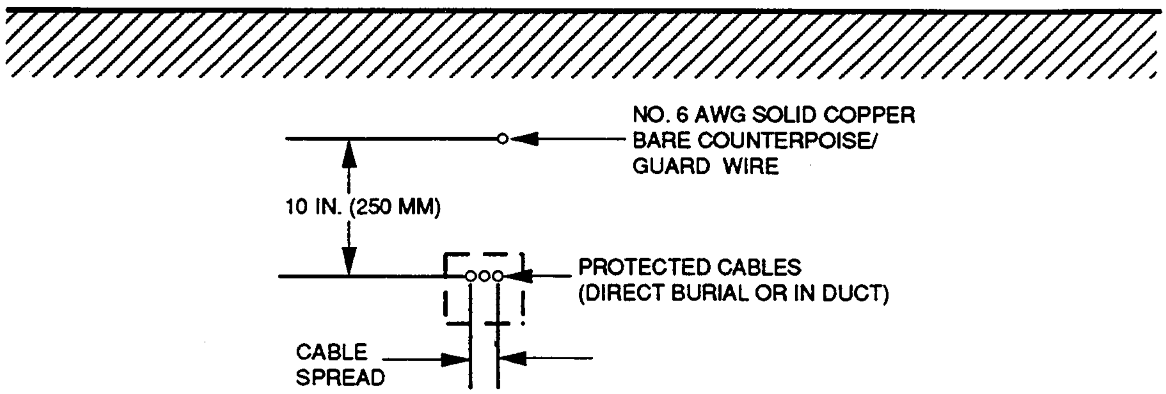
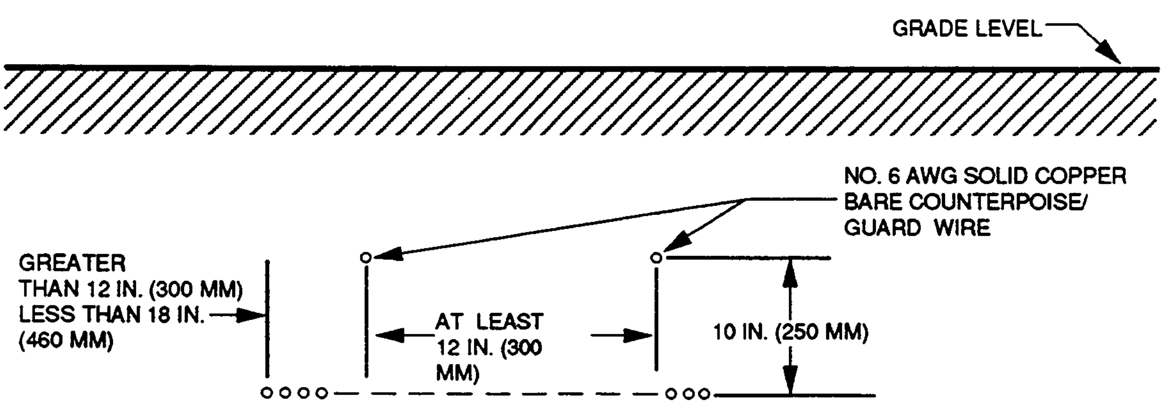


FIGURE 4-23. LIGHTNING PROTECTION FOR UNDERGROUND CABLES



(a) CABLE SPREAD WIDTH OF LESS THAN 3 FEET (0.9 METER)



(b) CABLE SPREAD WIDTH OF 3 FEET (0.9 METER) OR GREATER

SECTION 4. MULTIPOINT GROUND SYSTEM

106. **REQUIREMENTS**. The RCF multipoint equipment ground system consists of interconnected, normally non-current carrying, metal objects. The system is required by FAA-STD-019b to include at least two low impedance electrical paths to the earth electrode system. This system connects equipment frames, cabinets, racks, conduits, wireways, cable trays, outer cable shields, steel structure, and interconnection conductors. The multipoint ground system provides low impedance ground paths between interconnected metal in various locations within the facility and interconnected metal ground plates within the facility to the earth electrode system.

107. **INSTALLATION**. The multipoint ground system is designed to protect electronic equipment from potential differences and static charge buildup. The multipoint ground system shall be separate from the single point ground system, except after a main ground plate. From that main ground plate both systems share a common conductor directly to the earth electrode system. The AC protection ground (green wire) must maintain a separate path and must connect to the earth electrode system only at the service disconnect means and at the power company ground. A buried cable connection is recommended from the power company ground to the earth electrode system. Separation of these three grounding systems minimizes sharing interfering transient currents, potentials, and faults. The multipoint ground system shall use copper conductors with green insulation and an orange tracer. Each facility shall use a multipoint ground plate and branch plates as necessary, as seen in Figure 4-1, Typical Facility Ground System. An RCF having four or fewer multipoint ground wires may connect its ground wires directly to the main ground plate, not close to the single point ground connection, and use no multipoint ground plate.

a. **Multipoint Ground Plate**. The multipoint ground plate shall be a 6 inch by 4 inch by 1/4 inch copper plate mounted on insulated spacer material and secured with insulated hardware as illustrated in Figure 4-24, Multipoint Ground Plate. Ground plates and buses shall be identified with a permanently attached nonconductive cover label that is predominantly green with distinguishing bright orange slashes. The label shall bear the caption ELECTRONIC MULTIPOINT GROUND in black characters. This marking and labeling can be on a plastic cover (with suitable length spacers) over the copper plate.

b. **Multipoint Branch Ground Plates**. Multipoint branch ground plates shall be used to minimize the number of independent wire runs to the multipoint ground plate. The number and location of branch plates is dependent upon site requirements. An illustration of a facility multipoint ground system is shown in Figure 4-25, Multipoint Ground Installation.

FIGURE 4-24. MULTIPOINT GROUND PLATE

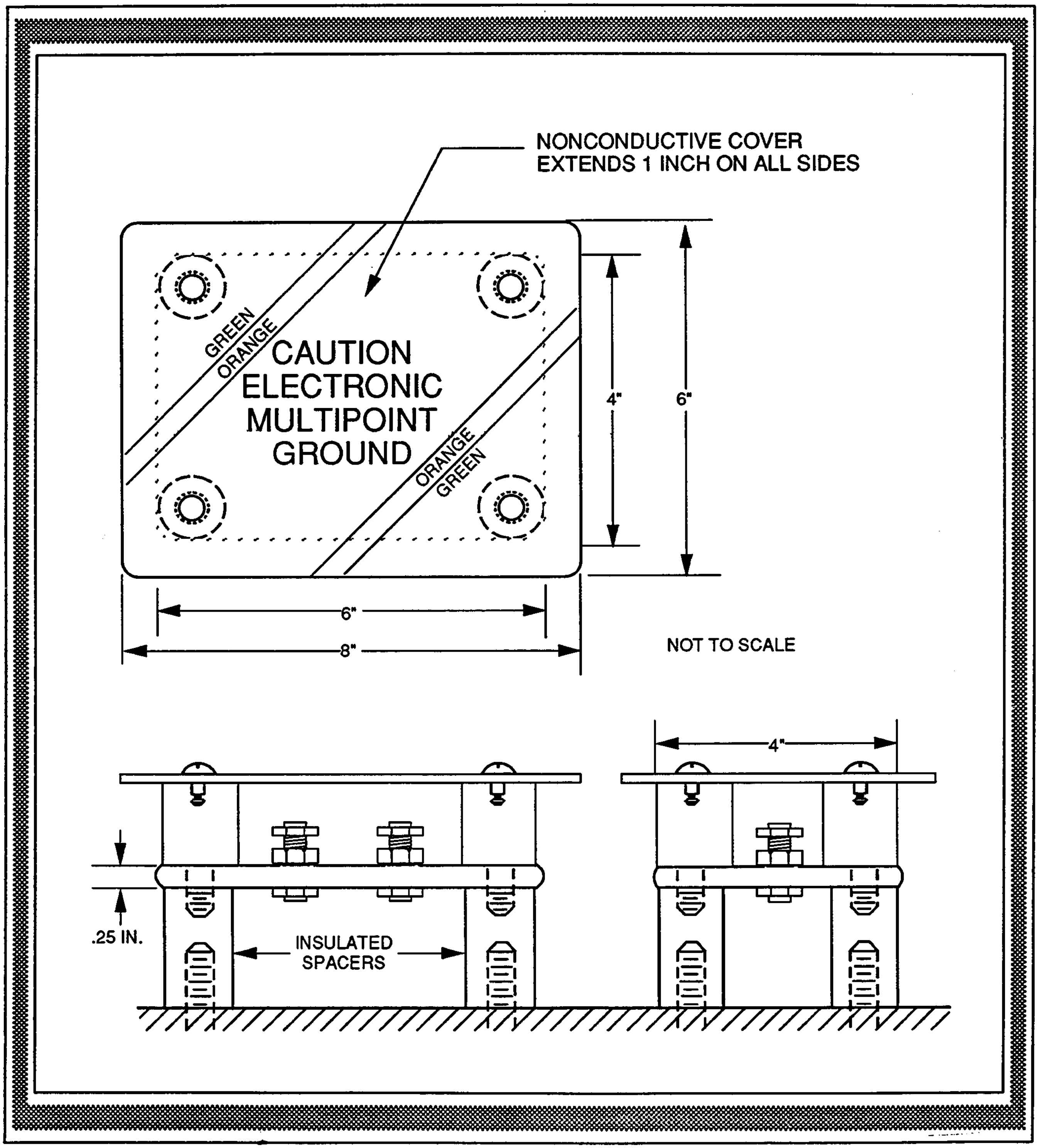
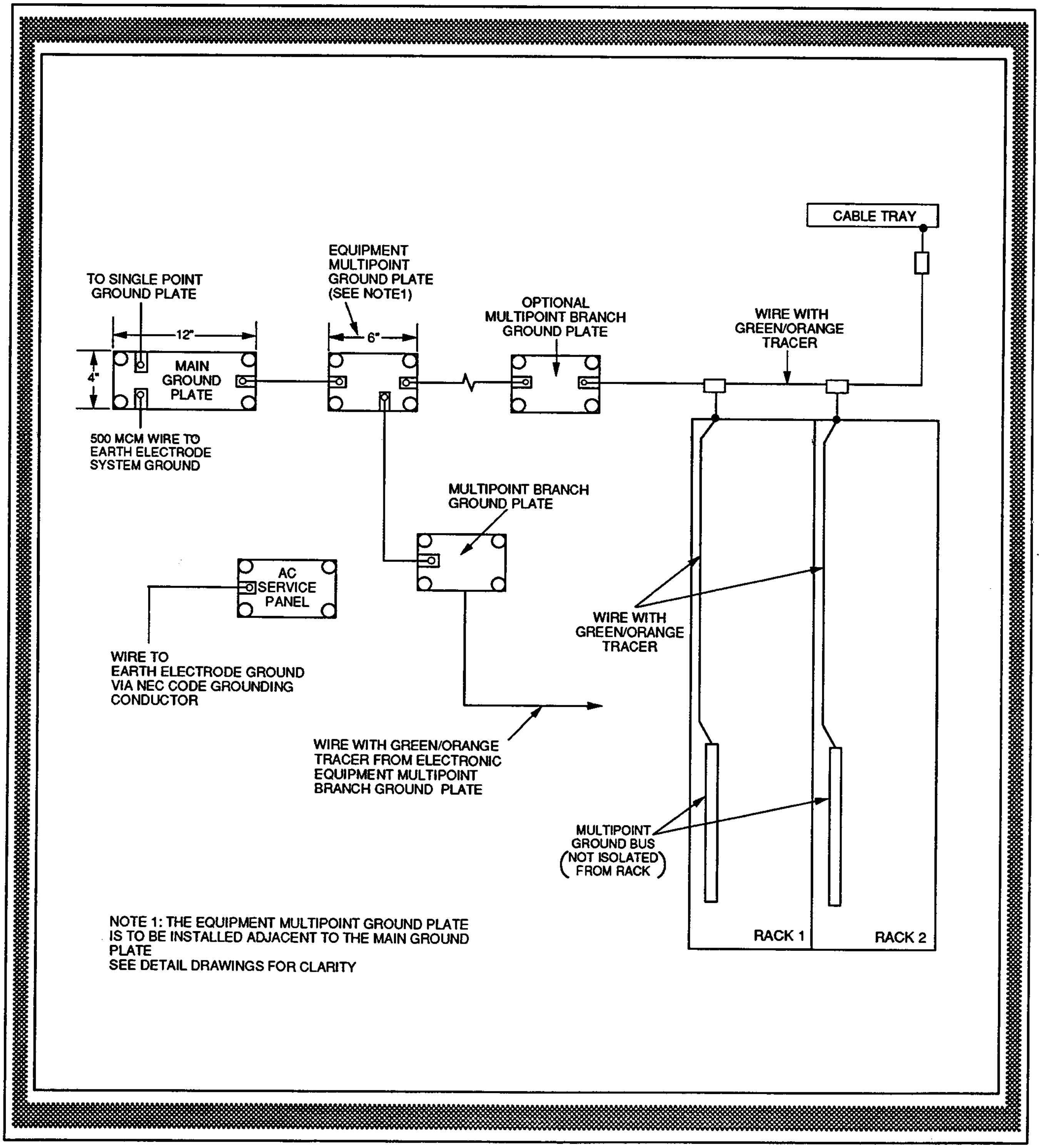


FIGURE 4-25. MULTIPOINT GROUND INSTALLATION



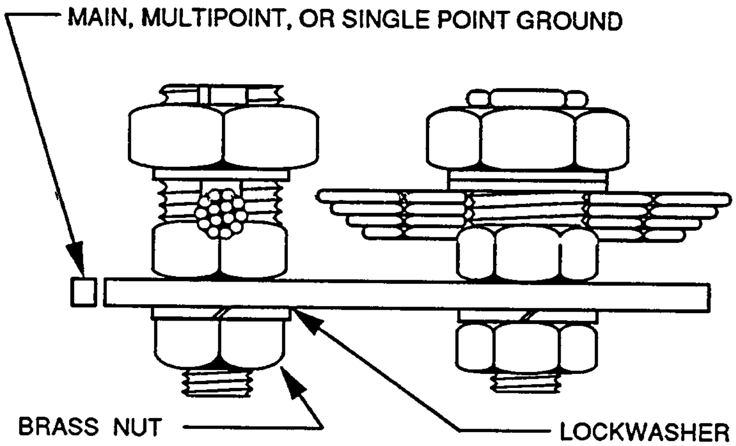
c. **Multipoint Ground Conductor**. A series daisy chain arrangement shall be used to interconnect the multipoint ground plate with each section of conduit, wireway, and cable tray. This conductor arrangement is used to interconnect equipment frames, cabinets, racks, and equipment chassis. The connection from multipoint ground to the metal cabinets shall be via a pressure type connector as shown in Figure 4-26, Split Bolt Ground Connection. Orange vinyl tape shall be added to a green insulated wire if green with orange tracer insulated copper conductor is not available. Conductor sizes and lengths that shall be used are specified in FAA-STD-019b and appear in Table 4-3, Sizes of Grounding Cable.

NOTE: Ensure that any paint or other nonconductive finishing has been removed in the vicinity of the bolt to provide good metal to metal electrical contact.

d. **Structures**. All structural members of a steel-framed building shall exhibit a one milliohm or less bond resistance at each joint. These joints shall be welded, brazed, or bolted. Where junction resistance is not low enough, one or more ground straps shall be installed across the joint. The structure shall be connected to the earth electrode ground system.

108.-112. **RESERVED**.

FIGURE 4-26. SPLIT BOLT GROUND CONNECTION



SOURCE:
BURNDY KC 22 OR EQUAL

NOTES:
a. USE STUDDED SPLIT BOLT CONNECTOR, MINIMUM WIRE SIZE #2 AWG, BONDING LUG FOR ALL GROUND PLATES.

TABLE 4-3. SIZES OF GROUNDING CABLE

Cable Size	Path Length Maximum		Bus Bar Size		Path Length Maximum	
AWG	Ft.	(m)	Inch	(mm)	Ft.	(m)
750 MCM	375	(114.3)	4 x 1/4	(100 x 6.4)	636	(193.9)
600 MCM	300	(91.4)	4 x 1/8	(100 x 3.2)	318	(96.9)
500 MCM	250	(76.2)	3 x 1/4	(75 x 6.4)	475	(145.1)
350 MCM	175	(53.3)	3 x 1/8	(75 x 3.2)	238	(75.2)
300 MCM	150	(45.7)	2 x 1/4	(50 x 6.4)	318	(96.9)
250 MCM	125	(38.1)	2 x 1/8	(50 x 3.2)	159	(48.5)
4/0 AWG	105	(32.0)	2 x 1/16	(50 x 1.6)	79	(24.1)
3/0 AWG	84	(25.6)	1 x 1/4	(25 x 6.4)	159	(48.5)
2/0 AWG	66	(20.1)	1 x 1/8	(25 x 3.2)	79	(24.1)
1/0 AWG	53	(16.2)	1 x 1/16	(25 x 1.6)	39	(11.9)
1 AWG	41	(12.5)				
2 AWG	33	(10.1)				
4 AWG	21	(6.4)				
6 AWG	13	(4.0)				
8 AWG	8	(2.4)				

Note: Where these cables are not available, parallel cables may be used such as three, 250 MCM cables in place of one 750 MCM cable, or two, 300 MCM cables in place of one 600 MCM cable.

SECTION 5. SINGLE POINT GROUND SYSTEM

113. **REQUIREMENTS**. The RCF single point ground system provides an isolated, single ended, low impedance electrical path from shields of low voltage data, communication, and control cables to the earth electrode system. Grounded reference shields must be isolated and grounded at the source end only to prevent loops in the single point ground system. To provide a noise-free ground reference, the single point ground system shall be isolated from the multipoint ground system, except after the facility main ground plate. From the main ground plate both systems share a common conductor directly to the earth electrode system. The single point ground bus shall be isolated copper bars or plates suitable for termination of cable shields and of cables to branched ground plates. Cable shield pigtails terminated on the single point ground bus shall be as short as possible to minimize inductance. Cables connected to single point ground plates and to the single point ground connection on the main ground plate shall be insulated copper conductors coded green with a yellow tracer and must be isolated from all other grounding systems. Branch plates shall be used as needed in order not to violate the isolated, non-looped, single-ended, tree configuration of the single point ground system.

114. **INSTALLATION**. The single point grounding system shall be isolated from all other grounding systems except at the tie-in to the main ground plate.

a. **Single Point Ground Plate**. Single point ground plates shall be 6 inch by 4 inch by 1/4 inch copper plates, or larger, mounted on insulated spacer material and secured with insulated hardware as shown in Figure 4-27, Single Point Ground Plate. Single point ground plates and buses shall be identified with a permanently attached non-conductive cover label that is predominantly green with distinguishing bright yellow slashes. The label shall bear the caption ELECTRONIC SINGLE POINT GROUND in black characters.

b. **Equipment Cabinet Single Point Ground Bus Bar**. A solid copper single point ground bus bar, mounted on insulators, shall be installed in each applicable equipment cabinet. A typical single point ground bus bar is approximately 3/4 inch wide, 1/4 inch thick, and 16 inches long. It is mounted horizontally in the equipment cabinet. Isolation from the cabinet shall be provided by standoff insulators. Each RCF single point ground shall be insulated from the cabinet and all other grounds. An illustration is given in Figure 4-28, Single Point Ground Installation.

FIGURE 4-27. SINGLE POINT GROUND PLATE

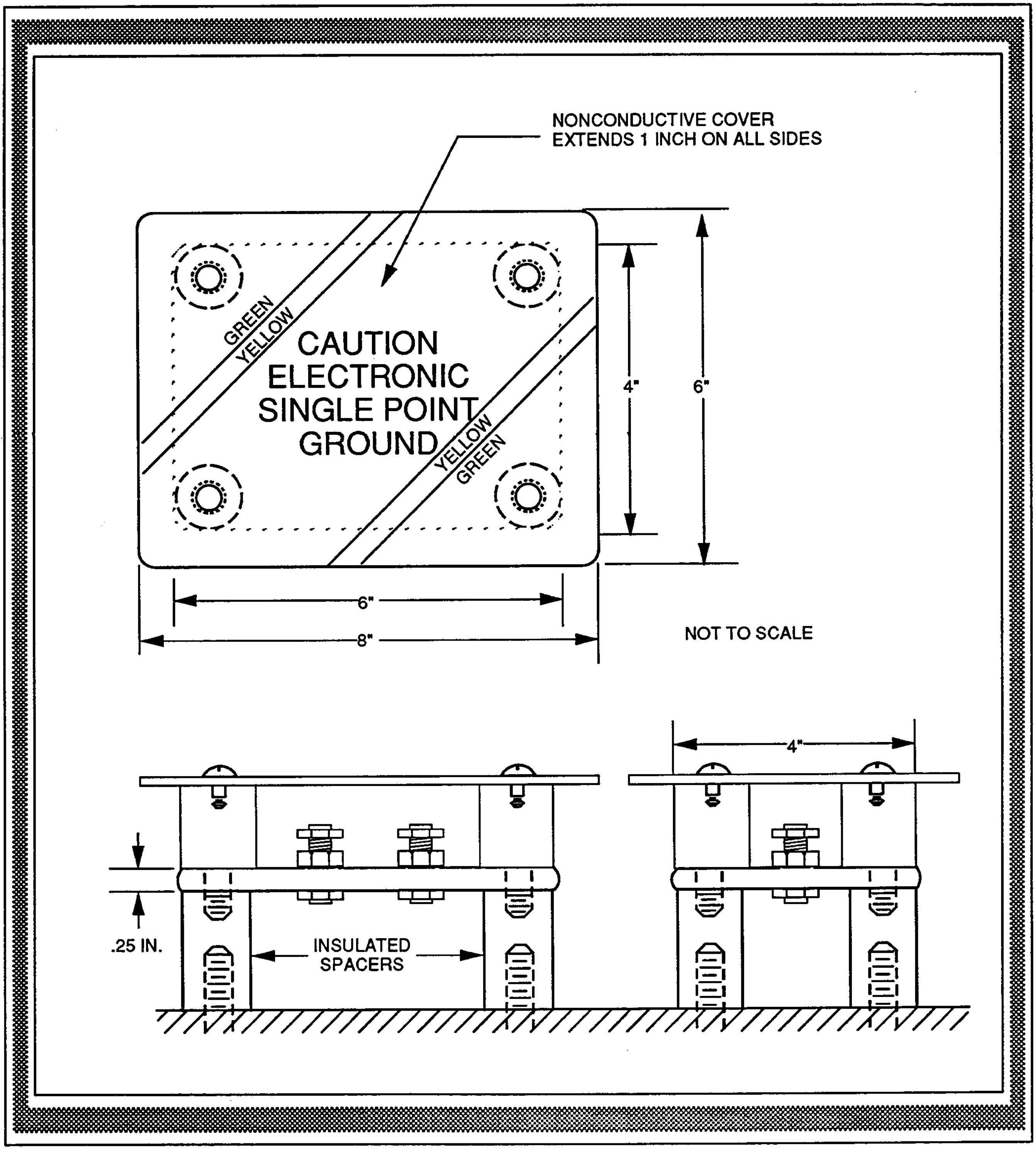
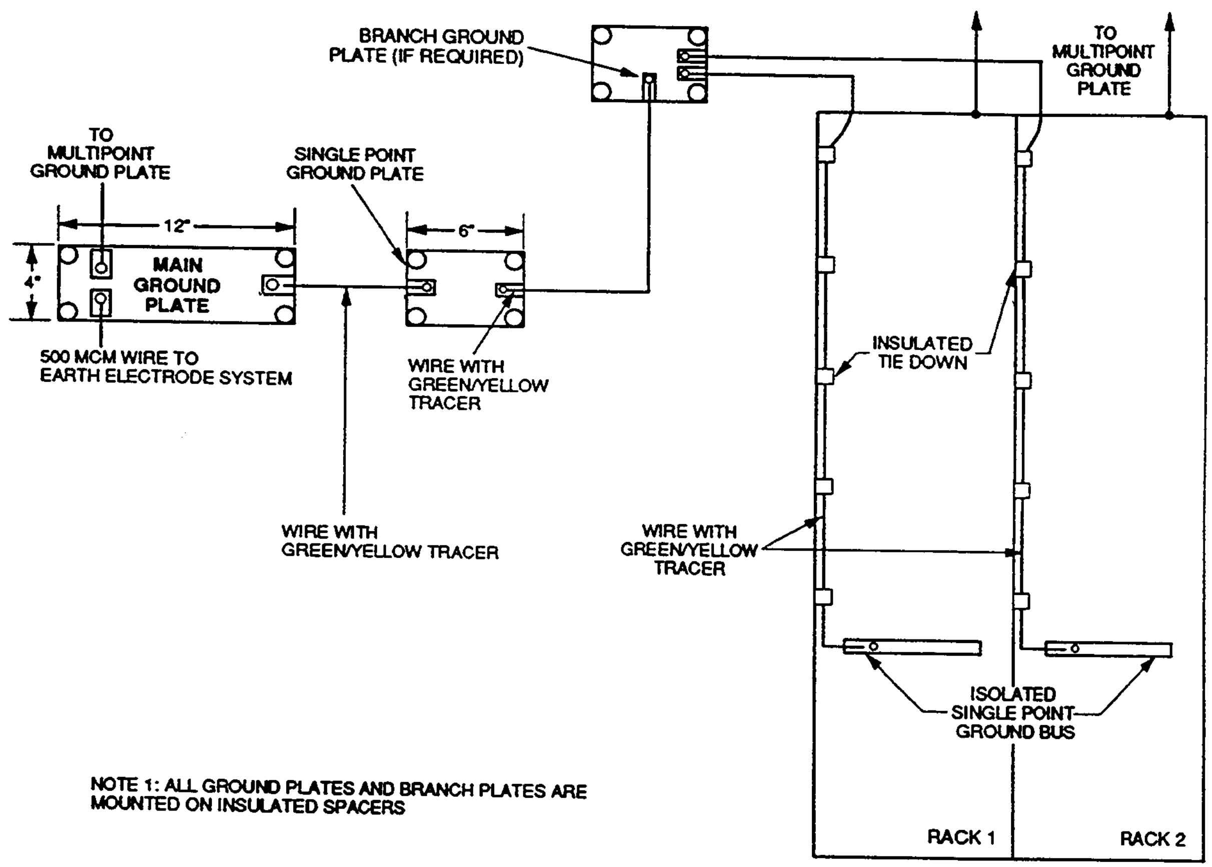


FIGURE 4-28. SINGLE POINT GROUND INSTALLATION



c. **Interior Single Point Ground Conductors**. A green with yellow tracer insulated copper conductor shall be installed from the equipment single point ground lug to the equipment cabinet single point ground bus. The single point ground conductor for each cabinet shall be connected separately to a single point ground plate or branch plate. Conductor size and length shall comply with FAA-STD-019b.

115.-119. **RESERVED**.

SECTION 6. TRANSIENT AND SURGE PROTECTION SYSTEM

120. **REQUIREMENTS**. An operating system comprised of electrical power, communication, and electronic equipment is susceptible to two types of lightning effects. These lightning effects are surges on AC power lines and transients on signal and control landlines connected between an external equipment or structure and a facility. Damage from lightning can be minimized, and in most instances eliminated, by properly using the following protection methods.

121. **AC POWER PROTECTION**. Protection from AC power surges caused by lightning shall be provided by the use of surge arresters on the supply side of incoming power lines at the facility service disconnect means and at the entrance at interconnected facilities. See single and 3-phase service in Order 6950.19. Arresters limit the induced voltage by routing excess current to earth until surges are dissipated. These devices shall be sized to limit to an acceptable level the AC voltage supplied to RCF equipment. Ratings for these devices are found in FAA-STD-019b and FAA-STD-020.

a. **Pre-installation Tasks**. An existing facility will require the following major pre-installation actions prior to the actual installation of the lightning and electrical surge protection circuit equipment.

(1) **Evaluation of Existing Surge Protection**. Determine if the facility AC entrance power circuits have lightning protection circuits currently installed. If the protection equipment installed is operating satisfactorily and has operating parameters equivalent to those of the equipment specified herein, no further action is required.

(2) **Voltage and Phase of AC Power Service**. Determine whether commercial power supplied to the facility is 240 VAC single phase or 208 VAC 3-phase service. Obtain a surge arrester that is compatible with the facility entrance power. More specific guidance is provided in FAA documents, FAA-C-1217e, Electrical Work, Interior, FAA-STD-019b, and Order 6950.19.

(3) <u>Coordination of System Shutdown</u>. Request the issuance of a NOTAM and coordinate systems shutdown with the control facility. Ensure that all systems receiving commercial AC power via the service entrance switch are properly removed from service (i.e., RCF, NAVAIDS or VHF Omnidirectional Range (VOR)). Some systems may continue to operate satisfactorily from their standby power over the approximate 2 hours required for system downtime. Coordination with operating personnel is required in either situation.

(4) <u>Location of Surge Arrester</u>. Surge arresters shall be mounted on incoming AC lines on the supply side of the main service disconnect switch per FAA-STD-019b. An arrester junction box shall be located immediately adjacent to the main AC service disconnect (1 foot away maximum). All arrester elements shall be isolated from the junction box by a minimum of 10 megohms resistance. An isolated arrester ground shall be connected directly to an earth electrode cable with No. 6 AWG wire coded green with red tracer or via the main service disconnect bus to the earth electrode system by a 600 volt insulated white No. 4 AWG stranded copper conductor.

b. <u>Installation Tasks</u>. Install the AC power surge arrester at the selected location on the incoming AC power lines. If the arrester cannot be mounted directly adjacent to the main service disconnect switch as illustrated in Figure 4-29, Single Phase AC Power Surge Arrester Installation, or Figure 4-30, Three Phase AC Power Surge Arrester Installation, site adaption will be required. It is important to keep connections to the arrester as short as possible with no loops or sharp bends.

(1) <u>Operating System Outage</u>. The team supervisor shall request the issuance of a NOTAM to inform the control facility and coordinate system shutdown.

(2) <u>AC Entrance Power</u>. If possible, install the surge arrester on the supply side before the main service disconnect switch. If removing AC service is not possible, open the main service disconnect switch to install the arrester after the main service disconnect switch but before the fuses in the load lines.

NOTE: Verify that AC power is disconnected before proceeding. Be very cautious when working in the vicinity of commercial service AC power.

(3) <u>Arrester Installation</u>. Install the AC power surge arrester and verify that the installation is in accordance with figure 4-29 or figure 4-30, whichever is applicable. Refer to Table 4-4, Materials For AC Power Surge Arrester Installation, for material typically used in the enclosure. Follow the manufacturer's special requirements where applicable. Close the covers on the

FIGURE 4-29. SINGLE PHASE AC POWER SURGE ARRESTER INSTALLATION

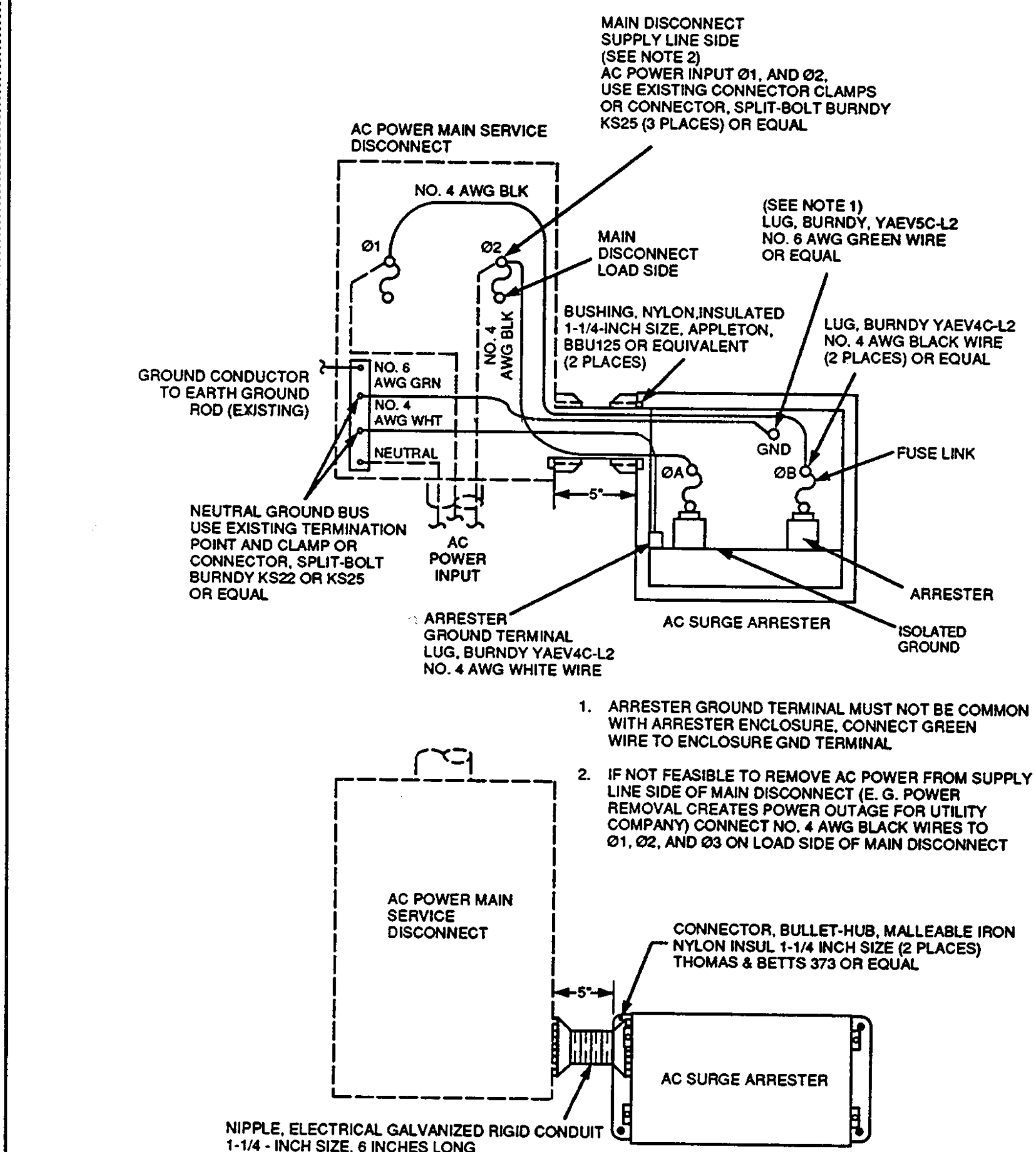


FIGURE 4-30. THREE PHASE AC POWER SURGE ARRESTER INSTALLATION

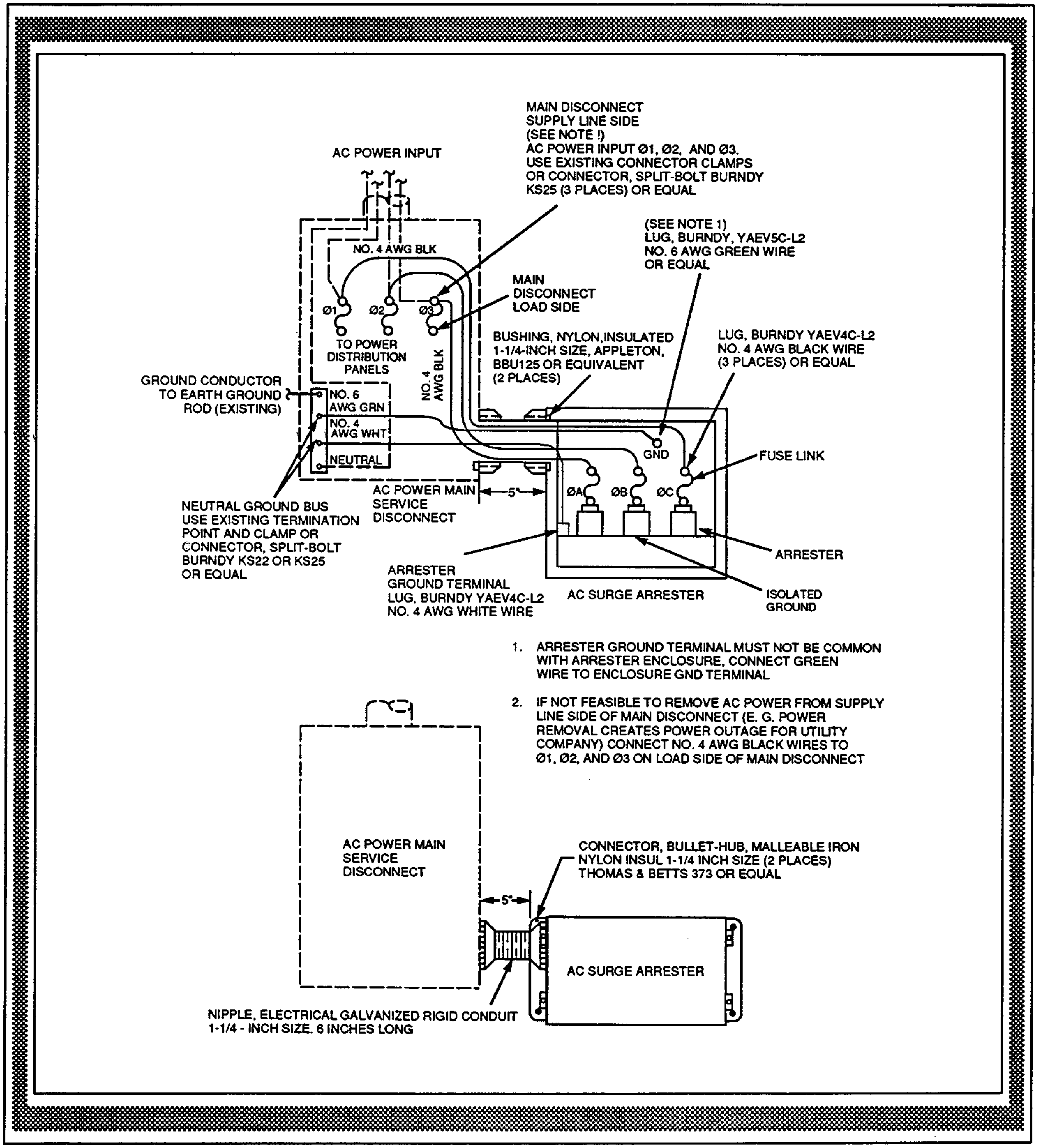


TABLE 4-4. MATERIALS FOR AC POWER SURGE ARRESTER INSTALLATION

ITEM	DESCRIPTION	QUANTITY
1.	Lightning and electrical surge arrester 120/240V AC, 1-phase, 3-wire, grounded neutral, NSN 5920-01-146-2112	As Required
2.	Lightning and electrical surge arrester, 120/208V AC, 3-phase, four wire, NSN 5920-01-146-2111	As Required
3.	Connector, conduit, bullet-hub, nylon insulated, malleable iron, 1-1/4 inch, or equal	2 each
4.	Nipple, electrical, galvanized, rigid conduit, 1-1/4 inch by 6 inches	1 each
5.	Bushing, nylon, insulated, 1-1/4 inch Appleton BBU125 or equal	2 each
6.	No. 6 AWG (Green) stranded, 600 V AC, THW wire	As Required
7.	No. 4 AWG (Black) stranded, 600 V AC, THW wire	As Required
8.	No. 4 AWG (White) stranded, 600 V AC, THW wire	As Required
9.	Connector, split-bolt, Burndy KS22 or equal	1 each
10.	Connector, Split-bolt, Burndy KS25 or equal	1 each
11.	Connector, Burndy SERVIT Post Type K2C22, or equal	As Required

arrester enclosure and the covers on the service entrance switch enclosure. Restore the AC power to all RCF systems and ensure that they are operational.

c. **Documentation**. Redline all applicable facility drawings. Review the manufacturer's data furnished with the arrester for theory of operation and maintenance data. Provide the site management with all applicable documentation for filing with the facility.

122. **TRANSMITTER/RECEIVER PROTECTION**. Each RF coaxial line not protected by continuous ferrous conduit shall have installed at the facility entrance a feedthrough coaxial transient suppressor with an isolated ground to protect equipment from conducted transients. An example of feedthrough coaxial cable transient suppressors appears in Figure 4-31, Coaxial Transient Suppressor Mounting.

123. **LANDLINE PROTECTION**. Transient suppressors, either feedthrough or in junction boxes, shall be installed at RCF and support facilities to protect equipment from landline conducted transients in accordance with FAA-STD-019b. Multiconductor landlines shall be protected by transient suppressor hybrid circuits which limit peak voltage while shunting excess current to the earth electrode system. Figure 4-32, Landline Protector Circuit Assembly Installation, shows a multipair landline example. Suppressor elements shall be grounded to lightning protection circuit bus bar A. All ground leads must be as short as possible. Verify that bus bar A and its ground leads are isolated from all other ground systems by at least 1 megohm before connection is made to the earth electrode system. Bus bar A shall be connected as directly as possible to the earth electrode system with No. 4 AWG insulated stranded copper wire coded green with red tracer. Ground buses A and B shall be isolated from the junction box and from each other. Ground bus bar B shall be connected to the single point ground system with No. 6 AWG insulated copper wire coded green with yellow tracer. The junction box shall be connected to the multipoint ground system with No. 6 AWG insulated copper wire coded green with orange tracer.

a. **Pre-installation Tasks**. Adequate planning must be performed before any changes are made to lightning protection equipment. Prior notice of any system shutdown must be given for all affected systems.

(1) **Evaluation of Existing Protection Equipment**. The installation of lightning protection circuits and landline lightning protection equipment is applicable to all RCF's and their associated control facilities, including those facilities which have leased landline equipment. In some instances, a host navigational aid facility interfacility landline demarcation box may have to be enlarged to accommodate the RCF landlines. Table 4-5, Existing Installation Lightning Protection Circuits Material, shows a list of

FIGURE 4-31a. COAXIAL TRANSIENT SUPPRESSOR MOUNTING

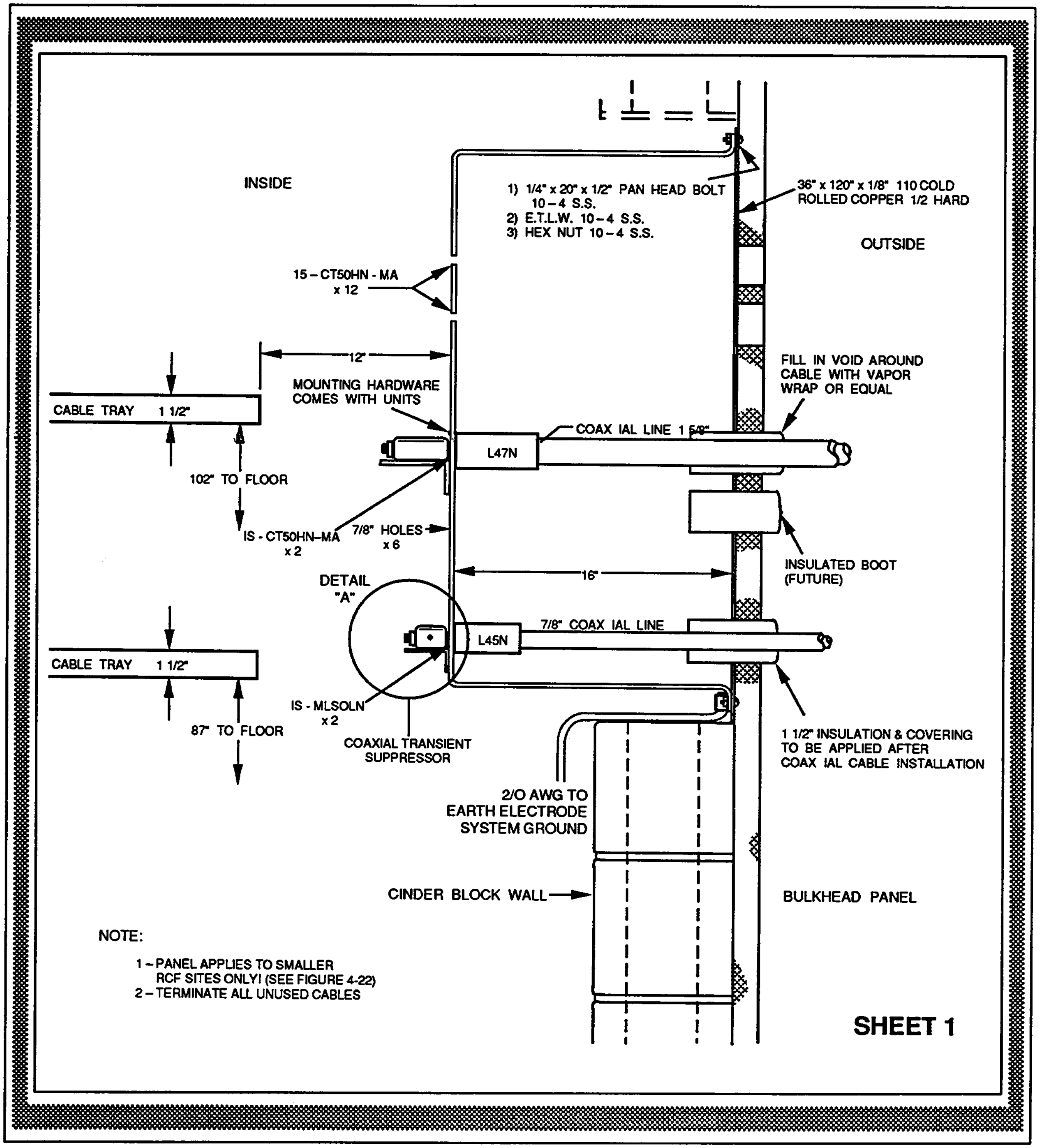


FIGURE 4-31b. COAXIAL TRANSIENT SUPPRESSOR MOUNTING

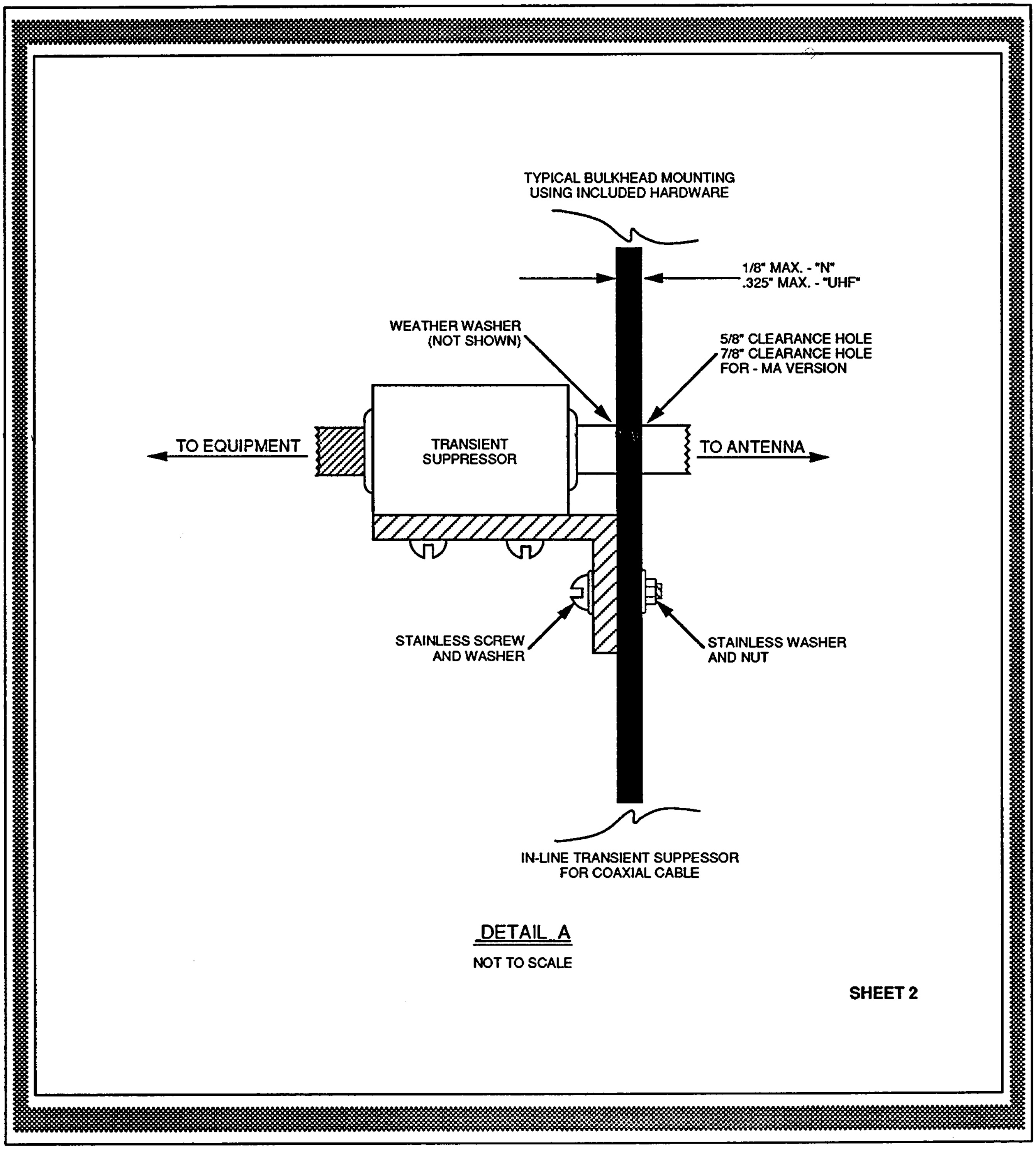


FIGURE 4-32. LANDLINE PROTECTOR CIRCUIT ASSEMBLY INSTALLATION

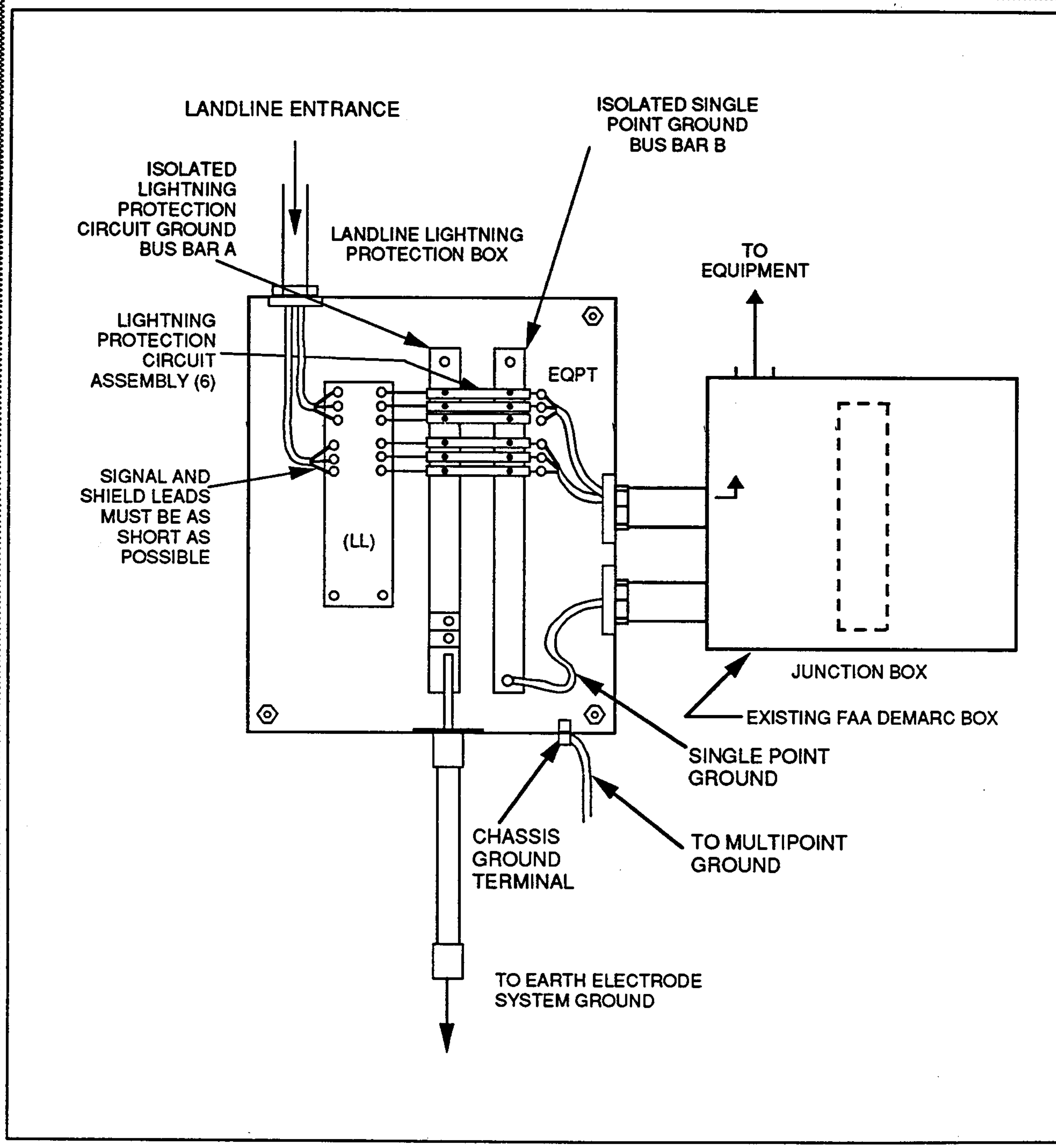


TABLE 4-5. EXISTING INSTALLATION LIGHTNING PROTECTION CIRCUITS MATERIAL

ITEM	DESCRIPTION	QUANTITY
1.	Screw, machine, No. 6-32x1/2-inch	8 each
2.	Lockwasher, No.6, split, silicon	8 each
3.	Washer, flat, No. 6, 5/16 inch	8 each
4.	Lug, spade, Thomas & Betts RA1203 or equal	12 each
5.	Splice, insulated, Burndy INSULINK, Type SN18, or equal	As Required
6.	No. 22 AWG wire, twisted pair, solid, copper red and black, Alpha 1793, or equal	As Required
7.	Lightning Protection Circuit Assembly, Type PA3-12, printed wiring board, NSN 5920-01-046-4246	As Required

materials used for the addition of new protector assemblies. On other host facilities, the existing demarcation box may adequately accommodate the additional RCF landlines. If existing facility landline circuit protection has adequate hybrid devices properly installed, no further action is necessary. Under no circumstances should additional FAA landline protection circuits be used in parallel with telephone company-provided protection equipment. Any facility landline protection circuitry in which duplication is found must be corrected by removing the FAA landline protection equipment and retaining telephone company-installed protection equipment. If telephone company-provided protection equipment is found to be inadequate, the telephone company must be notified and be requested to upgrade its protection equipment.

(2) **Coordination of Systems Shutdown**. Request the issuance of a NOTAM and coordinate the shutdown of the systems affected by the temporary loss of audio and control functions.

b. **Existing Facility Installation**. Identify the facility's existing junction box where the landlines are first terminated (normally the facility's demarcation junction box). Installation of the new landline lightning protection junction box to the left of the existing junction box is preferred; physical and circuit constraints, however, may require a different location. A list of materials required for installation is listed in Table 4-6, New Installation Lightning Protection Circuits Material.

(1) **Wiring Signal and Equipment Grounds**. The new landline lightning protection junction box shall be wired into the RCF grounding system using a No. 4 AWG copper conductor. Refer to Figure 4-33, Landline Lightning Protection Installation, as a wiring guide.

(2) **Documentation of Junction Box Installation**. Redline all applicable facility drawings and provide facility management with all relevant documentation.

c. **New Facility Installation**. Install the lightning protection circuits in the new landline lightning protection junction box.

(1) **Lightning Protection Junction Box**. Identify all landlines in the interfacility demarcation junction box scheduled to receive the lightning protection circuits. Mark each line to identify its function. Measure and record on appropriate FAA forms all signal levels on each line. Remove any existing surge protection devices or circuits presently installed that are inadequate for the combination of new and existing equipment. Figure 4-34, Landline Junction Box

TABLE 4-6. NEW INSTALLATION LIGHTNING PROTECTION CIRCUITS MATERIAL

ITEM	DESCRIPTION	QUANTITY
1.	Terminal strip, barrier type, 10 terminal, Cinch 1-141 or equal	As Required
2.	Marker strip, 10 terminal, Cinch MS10-141	As Required
3.	Bar, ground bus, PA-45, per FAA Drawing D-6075-14	2 each
4.	No. 6 AWG, (green with yellow tracer), stranded, insulated copper wire	As Required
5.	Screw, machine, hexagon-head, 10-32 x 7/16-inches, brass, nickel-plated	2 each
6.	Nut, machine, hexagon-head,10-32, brass, nickel-plated	2 each
7.	Lockwasher, No.10, external tooth, silicon bronze, nickel-plated	8 each
8.	Insulator, nylon, PA-90, per FAA Drawing D-6075-32	2 each
9.	Insulator, ground bus, PA-90, per FAA Drawing D-6075-32	2 each
10.	Connector, split-bolt, Burndy Type KS17 or equal	2 each
11.	Lockwasher, No.6, split, silicon bronze, nickel-plated	8 each
12.	Washer, flat, No.6 5/16-inch brass, nickel-plated	8 each
13.	Compound, sealing, Chico A3, or equal	1 lb
14.	Tie wrap, nylon, Thomas & Betts TY-26M or equal	As Required
15.	Lightning Protection Circuit Assembly, Type PA3-12, printed wiring board, NSN 5920-01-046-4246	As Required

FIGURE 4-33. LANDLINE LIGHTNING PROTECTION INSTALLATION

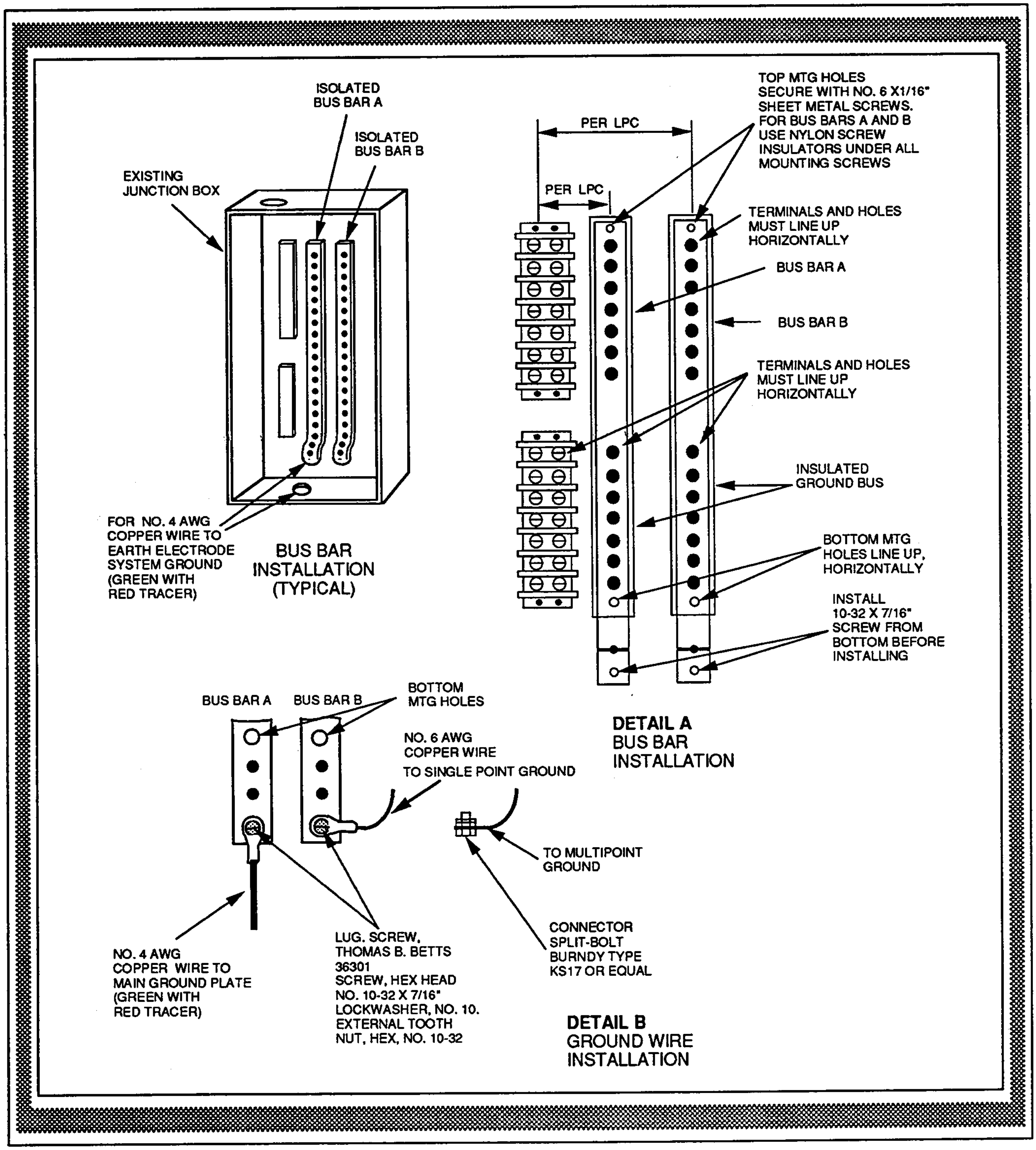
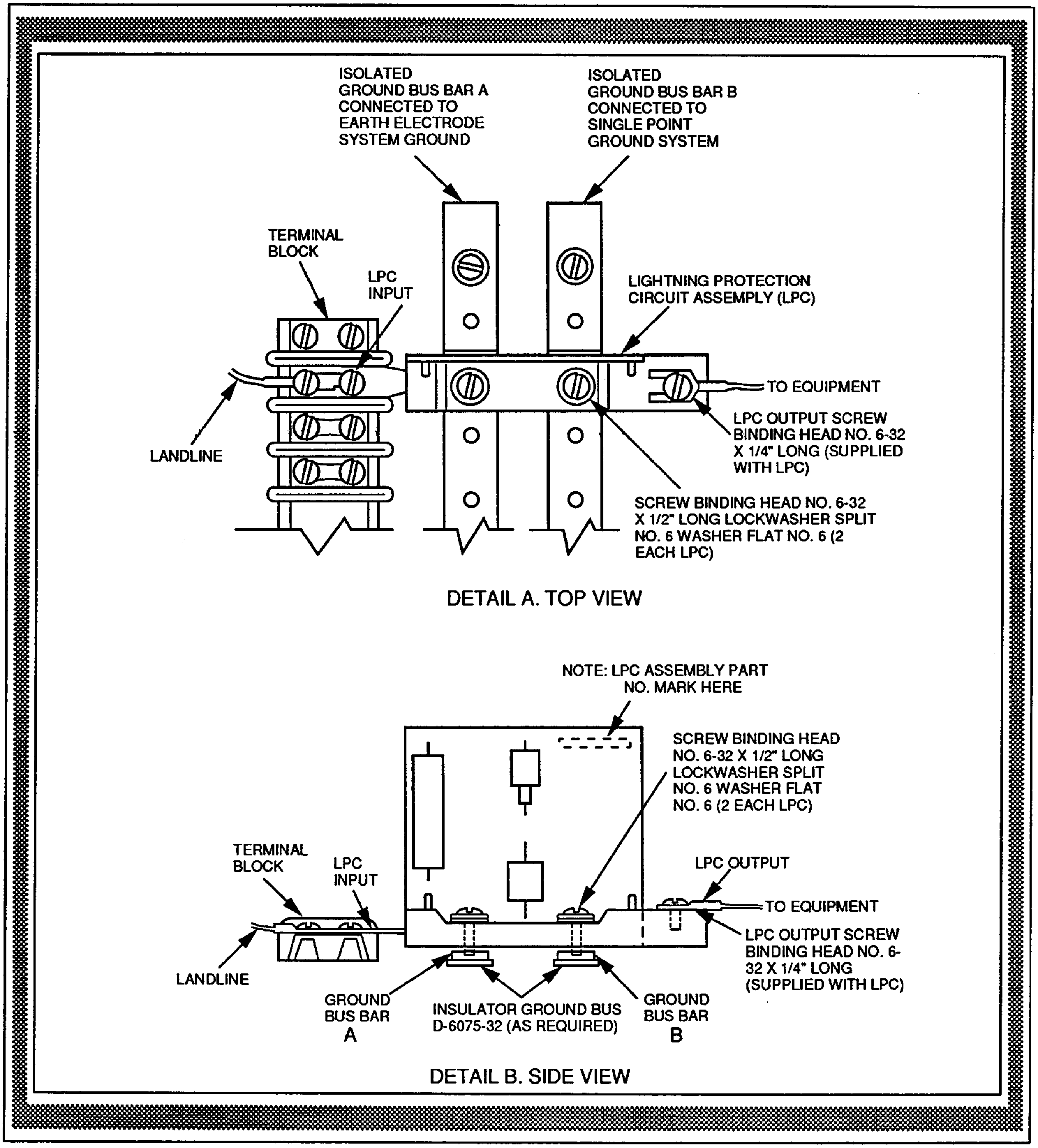


FIGURE 4-34. LANDLINE JUNCTION BOX INSTALLATION



Installation, shows assembly components. Describe the inadequacy and document the removal of existing devices.

NOTE: Appropriate caution shall be taken since low voltages exist on landlines.

(2) **Inspect Systems for Proper Operation.** Measure and verify the signal levels previously measured. Some loss in signal may occur.

(3) **Return Systems to Service.** Return all affected systems to full service.

(4) **Documentation of Installation.** Redline all applicable facility drawings. Review the manufacturer's data furnished with the lightning protection circuits for theory of operation and maintenance. Provide facility management with all applicable documentation.

124.-125. **RESERVED.**

SECTION 7. TESTING

126. **CRITERIA**. The ground systems installed at an RCF shall comply with grounding, bonding, shielding, and transient protection standards as stated in FAA-STD-019b. All ground connections shall exhibit a resistance value of less than 1 milliohm as measured across the junction of exothermic welds, clamps, and terminals. This measurement shall be made with a 4-terminal milliohm meter of sufficient sensitivity to measure junction resistance. Testing and inspections are necessary to certify compliance with FAA standards and requirements in NFPA-70, National Electric Code; NFPA-780, Lightning Protection Code; and UL-96A, Installation Requirements for Master Labeled Lightning Protection Systems.

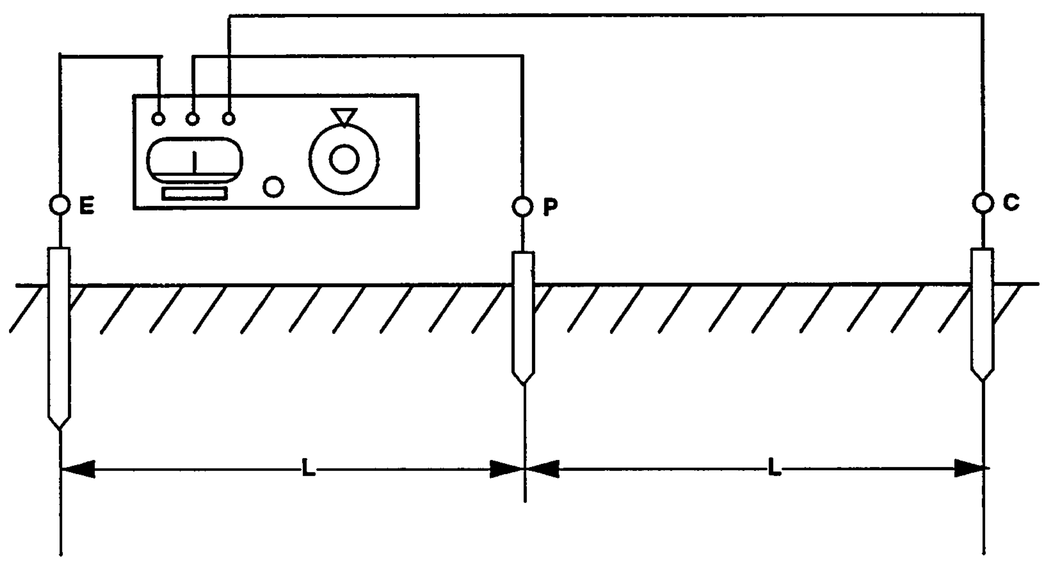
127. **EARTH ELECTRODE SYSTEM**. Testing of the earth electrode system requires an earth resistance tester, YEW Type 3235, or equivalent. Ensure the tester has had a valid calibration certification. An alternate four probe test set may be used in earth resistance measurements. Follow instructions provided in the equipment manual. The earth electrode system shall be tested and shall meet the resistance requirement of 10.0 ohms or less prior to the installation and subsequent to commissioning of RCF equipment.

a. **Drawings**. The engineering drawings associated with the RCF shall be reviewed to verify the location and dimensions of the existing earth electrode system or newly installed earth electrode system.

b. **Procedure**. The earth ground resistance of an existing or newly installed earth electrode system shall be measured without the RCF operating equipment, entrance power, and landline lightning protection equipment connected. An existing earth electrode system may not meet minimum resistance requirements because of system deterioration, improper installation, or site conditions. Detailed analysis and procedure can be found in Order 6950.20B.

(1) **Measure Earth Resistance**. Measure the resistance of the earth electrode system using an earth resistance tester. DO NOT test the earth electrode system within 72 hours following rain, or if the ground is frozen. The YEW 3235 resistance tester, illustrated in Figure 4-35, Earth Resistance Tester, passes a known current between probe E and probe C. Probe P, the potential balance probe, is placed midway between probes C and E. When the meter resistance knob is adjusted so the resistance bridge is balanced, the potentials from probe p to probes C and E are equal and the earth resistance is read from the dial. More than one earth resistance measurement must be made for each site. Maintain the same relative distances for the probes, more than four times the length of the longest ground rod as the distance between probes C and E with probe P midway between E and

FIGURE 4-35. EARTH RESISTANCE TESTER



NOTE: CONNECTIONS SHOWN ARE FOR YEW TYPE 3235.

LEGEND
E – EARTH GROUND ROD
P – POTENTIAL PROBE
C – CURRENT PROBE

c. Probe P may be offset up to 40 degrees from a line between probes E and C if necessary. Use the equipment manufacturer's instructions.

(2) **Locate Ground Rod**. To measure the earth resistance of an existing earth electrode system, find perimeter ground rods and their lengths using facility documentation. If necessary, use hand tools to dig a trench from the place where the facility ground conductor exits the building to a perimeter ground rod to locate other rods. Large facility earth electrode systems and systems with longer ground rods have larger electrical fields of mutual inductance. For such facilities the distance required between test probes E and C may have to be more than four times the longest ground rod length for accurate earth resistance measurement. Select a ground rod to use as probe E and make measurements as in (1) above.

(3) **Evaluation of Test**. Earth electrode system resistance of 10 ohms or less is low enough. Earth electrode system resistance higher than 10 ohms may cause unsatisfactory operation of facility equipment due to an improper single point ground reference level and can prevent surge and transient protection devices from properly protecting the facility. If measurements indicate an earth electrode system resistance is more than 10 ohms and facility operation is inadequate, the earth electrode system shall be repaired or upgraded. If the earth ground resistance of a newly installed earth electrode system exceeds 10 ohms, review the soil conditions and examine the system using paragraphs 88 through 92 in section 2 to determine the cause of the high resistance. Lower the resistance to 10 ohms, if possible, or at least until facility operation is entirely adequate.

128. **LIGHTNING PROTECTION SYSTEM**. Equipment that provides both lightning strike and conduction protection shall be inspected and tested for continuity and proper operation. A 4-terminal milliohm meter of sufficient sensitivity to accurately measure junction resistance shall be used to measure the resistance of all bonds, terminal connections, and joints in the lightning protection system. The zone of protection from lightning provided by air terminals shall be verified as adequate to meet the requirements for all facilities and equipment on site. All discrepancies found during the inspection shall be recorded in an inspection log. Discrepancies shall be corrected as soon as possible.

a. **Strike Protection**. The requirements for protection from lightning strikes shall be fulfilled by air terminals, down conductors, and the earth electrode system.

(1) **Air Terminals**. Inspect all air terminals for proper material, size, and placement on the structure. Check each air terminal's location, length, and elevation reference with scale drawings defining the zone of protection for site structures. If no

such drawings are available, scale drawings shall be made of the zone of protection for the existing site to determine if all equipment and facilities on site are protected adequately. Inspect all mounting hardware for size and type and make sure all fasteners are properly tightened. Measure the resistance of connections to roof or down conductors and verify compliance with the required one milliohm maximum. Inspect all existing air terminals for damage from previous lightning discharges, corrosion, pitting, breaks, and deformities. Note all discrepancies in the inspection log.

(2) **Conductors**. Inspect down conductors for proper materials, size, and routing. Inspect all mounting hardware for the appropriate size and type, and make sure all fasteners are properly tightened. Measure the resistance of connections to air terminals and the main ground system and verify compliance or noncompliance with the required one milliohm maximum. Inspect to verify that each down conductor is bonded across all tower sections on its path to the bottom of the tower. Inspect buildings to verify that down conductors are bonded to any metal they come into contact with, or are close to, in their paths to the earth electrode system. Inspect all bends and verify that the bend radius is not less than 8 inches and the bend angle is not less than 90 degrees. Inspect all of the conductors and associated components of an existing system for corrosion, pitting, and damage from previous lightning discharges.

(3) **Zone of Protection**. The zone of protection is defined as the space between a 100 (up to 150) foot radius ball of lightning and a structure as the ball rolls up to, over, and down its air terminals. This zone is defined using arcs drawn to scale on elevation site drawings which show all structures, including air terminals and equipment located exactly, and all drawn to scale. The drawings shall include above ground transmission lines and cables, roof and tower conductors, and down conductors. If drawings are not available, actual measurements shall be taken and elevation drawings made to scale for use in verifying that existing overlapping zones of protection for site facilities and equipment provide adequate site protection. If existing protection is not adequate, air terminals can be lengthened, added, or moved to different positions to provide required protection.

b. **Surge Protection**. AC power line protection from lightning generated power surges requires the use of grounded ferrous conduit and power line surge arresters. Inspect surge arrester installation to see if adequate line-to-line or line-to-ground arresters are provided for the facility requirements. Verify by visual inspection that installation requirements are met and, where possible, measure junction resistance of bonds, terminal connections, and conduit ground connections, and verify conduit electrical continuity. The secondary

AC surge arrester junction box must be located less than 12 inches from the main service disconnect. Each surge arrester must be connected on the line side of the switch, or line side of the fuse inline to the load, with No. 4 AWG insulated copper wire without loops, sharp bends, or kinks. Visually inspect each arrester fuse. If an arrester fuse is blown, replace the arrester or fuse module.

c. **Transient Suppression**. Protection from conducted transients on communication, control, and status landlines entering a facility above or below ground requires the use of inline transient suppressors at the facility entrance, except for landlines run in watertight continuous ferrous conduit. Axial cables must use axial feedthrough transient suppressors. Unused wires in a cable must be grounded to their shield at each end. Verify by visual inspection and by resistance measurements that all installation requirements are met for connections, isolation, and continuity.

(1) **Axial Transient Suppressors**. Verify that coaxial, twin-axial, and tri-axial cables entering a facility at a bulkhead have shields properly grounded and that each axial cable is connected to a properly grounded feedthrough axial cable transient suppressor that meets equipment and non-degrading signal requirements. The shields of these transmission lines shall be terminated on a grounded bulkhead plate or on a grounding bar as they enter the building. Earth ground connection shall be made with a No. 2/0 AWG or larger copper wire. The connector plate or bar shall be tinned copper. All electrical paths to and from the transient suppressor shall be as short as possible and large enough to handle the surge current. Make sure separate electrical paths are provided when both high and low level transient suppressors are used. Low level transient suppressors are part of landline entry protection. Refer to figure 4-31.

(2) **Non-Axial Landline Transient Suppressors**. Verify that transient suppressor circuits for twisted pair and other non-axial landlines are provided in a separate junction box by the demarc box where landlines enter the facility. Transient suppressor bus bars A and B must be isolated from the junction box and from each other. Bus bar A must connect directly to the earth electrode system. Verify that suppressors are the proper size.

(3) **Conduit**. Verify that conduit is made of ferrous metal and has electrical continuity throughout its length. Conduit shall also be connected to earth ground at each end and, if the installed length is 300 feet or more, the conduit shall be connected to the earth ground every 100 feet.

(4) **Armored Cable**. Except for AC power cables, buried landlines which exceed 300 feet in length may use armored cable instead of conduit. Verify that where it enters the facility, armored

cable is bonded to the earth electrode system with a No. 2 bare copper wire, or to the main ground plate, if necessary. Verify that any other armor grounding complies with FAA-STD-019b.

(5) **Guard Wires**. Verify that cable with more than 3 feet not completely enclosed in ferrous conduit has a No. 6 AWG solid copper guard wire buried a minimum of 10 inches above the cable. The guard wire shall be connected to earth ground at the ends and every 300 feet when the wire exceeds this length. A cable run spread that is greater than 3 feet wide requires two or more guard wires.

129. **MULTIPOINT GROUND SYSTEM**.

a. **Ground Plate**. Verify each ground plate is of proper size and construction and is mounted properly. Inspect all connections to the ground plate and measure each with a 4-terminal milliohm meter. Each junction resistance shall measure 1 milliohm or less. Any connections that do not meet this standard shall be redone and shall be measured again to certify compliance with the specification.

129. b. **Electrical Paths**. Verify that at least two low impedance electrical paths exist from the multipoint ground system to the earth electrode system. Verify that the multipoint ground system is isolated from the single point ground system until the main ground plate. Measure the multipoint ground path resistance to ground with a 4-terminal milliohm meter to verify that it is 5.0 milliohms or less. Verify that all multipoint ground system cables are coded green with an orange tracer and are insulated from other ground systems.

c. **Building Grounding**. Facility building structural steel elements shall be grounded to the earth electrode grounding system.

(1) **Steel Buildings**. Verify that joints in a steel framed building are adequately bonded. Measure joints with a 4-terminal milliohm meter. Junction resistance shall be 1 milliohm or less. The resistance of bolted joints can be reduced as follows. Clean the joint with solvent, tighten the bolt to the proper torque, apply sealant, and remeasure the joint resistance. If the resistance is still greater than 1 milliohm, add 1 or more conductive jumpers across the joint until the junction resistance measures 1 milliohm or less. All steel building elements shall be grounded to the earth electrode system via conductors separate from the main ground plate conductor.

(2) **Non-Metallic Buildings**. Verify that all metallic elements of a non-metallic building are grounded to the earth electrode system directly or through the multipoint grounding system. Junction resistance shall measure 1 milliohm or less using a 4-terminal millohm meter. Repair faulty junctions to meet requirements.

130. **SINGLE POINT GROUND SYSTEM**.

a. **Ground Plate**. Verify that all single point ground plates are isolated, are the proper size and construction, and are mounted properly. Disconnect the main single point ground cable from the main ground plate to measure the isolation resistance between the plate and the cable. Isolation resistance must measure at least 10 megohms per FAA-STD-019b. If the resistance is lower, the single point ground system isolation has been compromised and must be restored. Disconnect each single point ground branch to measure its isolation and to locate and repair isolation violations. Measure junction resistance of each reconnected single point ground with a 4-terminal milliohm meter to verify resistance of 1 milliohm or less for each remade connection.

b. **Cables**. Verify that all cables used in the single point ground system are the correct size, are insulated from contact with other grounds, and are coded green with yellow tracer. Replace cables as necessary to meet the specification.

c. **Bus Bars**. Verify that single point bus bars are of proper size and material are are mounted in and isolated from equipment cabinets and junction boxes. Measure with a 4-terminal milliohm meter that the resistance across each connection to a bus bar is 1 milliohm or less. Verify that all cables connected to these bus bars are properly sized and marked.

131.-135. **RESERVED**.

CHAPTER 5. POWER DISTRIBUTION SYSTEM

SECTION 1. GENERAL

136. GENERAL POWER SYSTEMS. Many RCF sites require both AC and Direct Current (DC) power to operate equipment. Reconfiguration of both AC and DC load centers may be necessary when installing new A/G communications equipment at an RCF. A DC power distribution system which provides +24 Volts Direct Current (VDC) may be required at an RCF to support the associated equipment. The DC power distribution system is required to have redundant battery chargers/eliminators with appropriate interface circuitry that permits switching from one power source to another without interruption of service. AC and DC power system primary power source, capacity and characteristics are listed in Table 5-1, General AC Load Center Power/System Characteristics.

TABLE 5-1 GENERAL AC LOAD CENTER POWER/SYSTEM CHARACTERISTICS

Single Phase 240 VAC rms Input Feeder Requirements

SYSTEM TYPE	AC INPUT CURRENT	FEEDER SIZE	CIRCUIT BREAKER
3 channel	24 amps	10 AWG	30 amps
6 channel	45 amps	4 AWG	60 amps
12 channel	76 amps	1 AWG	100 amps

Three Phase 208 VAC rms Input Feeder Requirements

SYSTEM TYPE	AC INPUT CURRENT	FEEDER SIZE	CIRCUIT BREAKER
3 channel	15 amps	12 AWG	15 amps
6 channel	30 amps	10 AWG	30 amps
12 channel	50 amps	6 AWG	50 amps

AC Power Input Requirements for DC Power System

SYSTEM TYPE	BATTERY CHARGER	CABINET FANS	TOTAL POWER	TOTAL V/A
3 channel	2376 W	180 W	2556 W	2840
6 channel	4644 W	180 W	4825 W	5360
12 channel	7776 W	360 W	8136 W	9040

SECTION 2. AC POWER

137. **GENERAL**. Commercial AC power to the site provides power to operate AC powered equipment as well as providing power for the battery chargers/eliminators required for operation of DC powered systems. Commercial AC power is either single phase 240 VAC or three phase 208 VAC.

138. **AC POWER DISTRIBUTION**. AC power distribution shall be supplied from the main service disconnect panel via a master circuit breaker switch to the AC panelboard where the circuit breakers are mounted. These circuit breakers support the RCF equipment circuits and the battery chargers. A diagram of a typical AC power system is shown in Figure 5-1, Simplified AC Power Distribution System. As a general policy, AC panelboard circuit breakers shall be subdivided. Equipment shall be separated on the same phase into circuit breaker groups identified by the following groups:

a. Primary or main RCF equipment (transmitters, receivers, multicouplers, remote control equipment and battery chargers).

b. Secondary or standby RCF equipment (transmitters, receivers, multicouplers and remote control equipment).

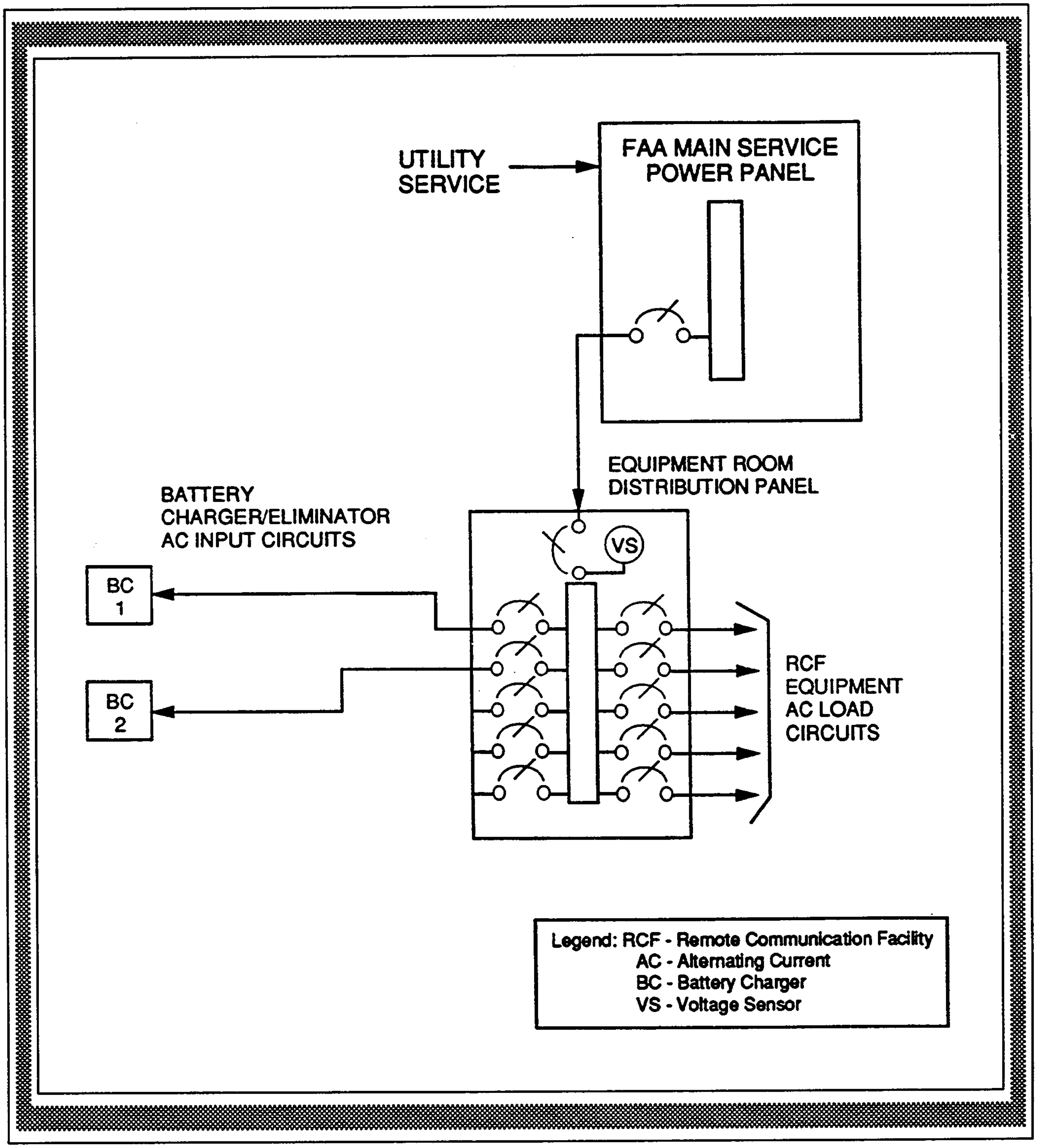
c. Commercial AC power source for utility items (lights, heating/cooling equipment and convenience outlets).

139. **GROUNDING REQUIREMENTS**. The RCF AC power ground system shall provide electrical system safety grounding in accordance with the NEC.

a. **AC Ground Conductor**. The AC ground conductor takes a separate path to the earth electrode system via the code grounding conductor. The AC power ground shall be connected to the barrier grounding bus of the main service panel. The ground conductor shall be terminated on the equipment case, utilizing approved fittings. The equipment AC power grounding conductor shall be copper with green insulation and installed in the same raceway as the branch AC circuit conductors feeding the equipment. Each branch circuit shall have its own equipment grounding conductor. The equipment ground conductor shall be sized in accordance with Table 95 in NEC 70, Article 250.

b. **System Components**. Several system components are necessary in order to meet the standards for AC power grounding systems. These systems may need to be upgraded when additional equipment is added to existing sites.

FIGURE 5-1. SIMPLIFIED AC POWER DISTRIBUTION SYSTEM



(1) **AC Power Wiring Ground**. The RCF equipment and rack AC power grounding conductor shall be installed in the same conduits, raceways, cable trays, etc., as the AC power branch conductors. If a power cord is used, the green conductor shall be integral with the branch conductors of the cord. Where a power cord terminates on a grounding type attachment plug, the equipment grounding conductor of the cord shall terminate on a fixed ground contact of the plug. For equipment supplied with AC power through a connector, the connector shall contain a grounding pin terminating the equipment grounding conductor to the connector pin. Do not rely on, or substitute conduits, or cable shields as the equipment grounding conductor even though they are electrically continuous and firmly bonded to the equipment case. All AC outlets shall be provided with the proper Underwriters Laboratory (UL) approved grounding receptacle.

(2) **Main Service Transformer Ground**. This is the grounding conductor between the main service transformer secondary center tap and the earth electrode system. Local power company approval shall be obtained before work is done on this system. Close coordination with the power company should be established before probing near active AC power cables.

(3) **Transformer Grounding Conductor**. At some host facilities, added power requirements may cause a need to increase the size of the grounding conductors between the main AC distribution transformer and the main AC service disconnect panel. Refer to the illustration in Chapter 4, Figure 4-1, Typical Facility Grounding System. Locate and uncover the grounding conductor between the main service transformer pad and the earth electrode system. Inspect the conductor for condition and proper size. The size of this grounding conductor between the transformer pad and the earth electrode system is based on the size of the largest service entrance power conductor. This conductor shall be a No. 2 AWG or larger copper conductor. The following chart will assist in selecting the proper conductor size.

NOTE: Do not use powered equipment. Use only hand tools!

Size of Largest Service-Entrance Conductor or Equal Area for Grounding	Size of Grounding Conductor
3/0 AWG through 250 MCM	2
350 MCM through 600 MCM	0
600 MCM through 1100 MCM	2/0
Over 1100 MCM	3/0

NOTE: To avoid injury and any possible equipment damage, TURN OFF the AC power at the transformer input prior to upgrading the main service transformer conductor to the earth electrode system. Coordinate all systems shutdowns with air traffic personnel.

(4) __Earth Electrode System Connection__. The RCF AC power ground system requires a conductor between the main service disconnect panel and the earth electrode system. The size of this conductor to the earth electrode system shall be based on the size of the largest service entrance power conductor or as referenced in Table 250-94 of the NEC. The conductor may be a No. 4 AWG or larger stranded copper conductor. A mechanical connection similar to the one shown in Figure 5-2, Main AC Service Ground Split Bolt Connection, shall be used to facilitate system ground testing. This is the only mechanical connection to the underground electrode system which allows this conductor to be disconnected during ground testing. The same conductor size used for the main service transformer ground shall be used for this conductor. All underground connections shall be exothermic welds.

140. __AC PANELBOARD__. The AC panelboard may be either single phase or three phase depending on the facility. A drawing of each type is shown in Figure 5-3, Typical Reconfigured RCF Single Phase AC Power Panelboard, and Figure 5-4, Typical Reconfigured RCF Three Phase AC Power Panelboard. These panelboards may have to be reconfigured to support new communications equipment. Following are steps necessary in adding breakers to support new equipment.

a. __Remove Entrance Power__. Commercial AC power is removed by opening the main breaker at the main power disconnect.

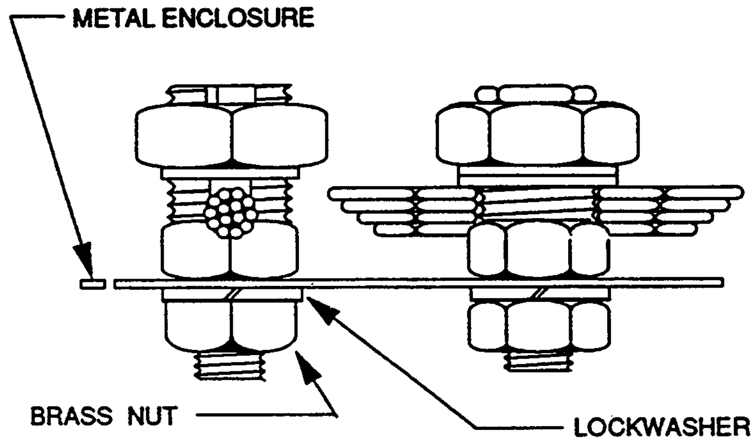
b. __Remove Front Panel__. Remove the AC panelboard front panel.

c. __Install Convenience Outlet Breakers__. A dedicated 15 Amperes AC circuit breaker shall be used for each group of three convenience outlets installed in the RCF racks. A single convenience outlet shall be mounted in the base of each rack with the exception of racks containing only DC voltage powered equipment. These racks shall not have AC voltage outlets permanently installed.

NOTE: Do not install AC convenience outlets in DC voltage equipped racks except on a temporary basis.

d. __Install Equipment Circuit Breakers__. A dedicated 20 amperes AC circuit breaker shall be used for the main equipment and a second dedicated 20 Amperes circuit breaker shall be used for the standby equipment. The main and standby multicoupler and control equipment shall be configured the same way. Each equipment group shall have a SEPARATE dedicated circuit breaker group.

FIGURE 5-2. MAIN AC SERVICE GROUND SPLIT BOLT CONNECTION



SOURCE:
BURNDY KC 22 OR EQUAL

NOTES:

a. USE STUDDED SPLIT BOLT CONNECTOR, MINIMUM WIRE SIZE #4 AWG, BONDING LUG FOR ALL DISCONNECT SWITCHES & METAL ENCLOSURES

b. REFER TO FAA-STD-19b FOR BOLT TORQUE SPECIFICATIONS

FIGURE 5-3. TYPICAL RECONFIGURED RCF SINGLE PHASE AC POWER PANELBOARD

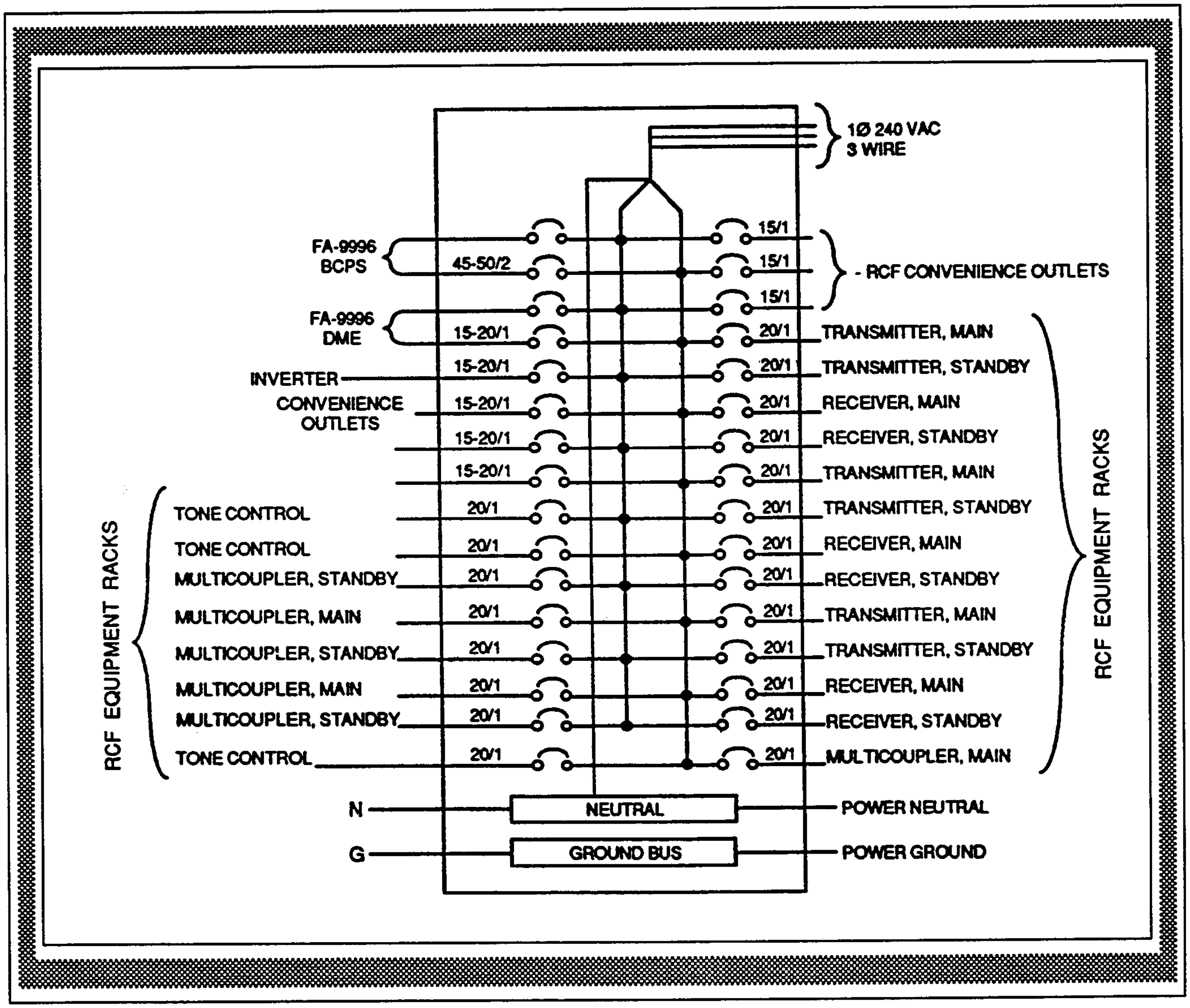
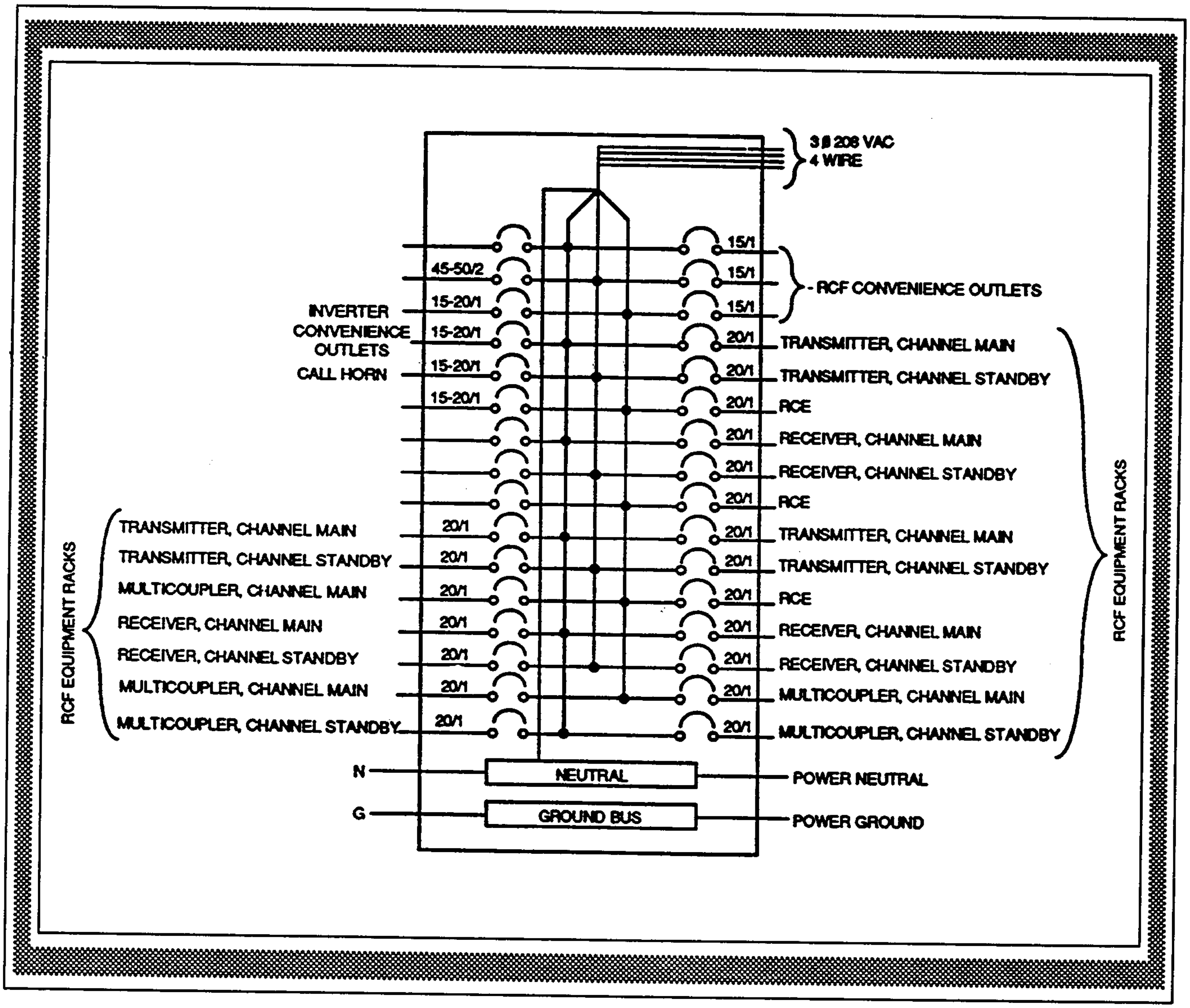


FIGURE 5-4. TYPICAL RECONFIGURED RCF THREE PHASE AC POWER PANELBOARD



141. **WIRING**. AC power wiring shall be done in accordance with FAA-C-1217e, Electrical Work, Interior. AC wiring shall never be routed with DC wiring, control cables, or RF cabling.

142.-145. **RESERVED**.

SECTION 3. DC POWER SYSTEM

146. **GENERAL**. The DC power distribution system consists of a DC power rack and a backup battery system containing additional battery charger systems. A DC to AC power inverter may also be employed to provide backup power to the Telephone Company (TELCO) trunk termination equipment. A block diagram of typical power distribution system is shown in Figure 5-5, Typical RCF Power Distribution Diagram.

147. **DC POWER DISTRIBUTION**. Control of DC power distribution shall be through the DC power rack. The DC power rack contains the battery chargers, load distribution panels, battery disconnect panel, alarm and monitor panel and the AC input panel. A typical rack configuration is shown in Figure 5-6, Typical DC Power Rack. The assemblies that make up the DC power rack shall be configured to support 3-channel, 6-channel, or 12-channel RCF communications system applications.

a. **Monitor Panel**. The monitor panel monitors A/G communications equipment functions, selected environmental building parameters, standby power source status, and site security. Alarm sensors shall provide serial digital signals to relay information on failures. Data is usually transmitted over a four-wire communications circuit on analog voice circuits. This does not cause interference to the voice signals. Microwave, UHF radio and fiber optic paths can also be used to transmit information to remote alarm monitoring equipment.

b. **AC Interface**. The AC input panel interfaces with the AC load center to provide power for the battery chargers and/or eliminators. A DC power distribution diagram for a battery charger is shown in Figure 5-7, Typical DC Load Distribution.

c. **Battery Disconnect Panel**. The manual battery disconnect panel allows discharging batteries to be disconnected from the load when system voltage drops below a pre-set minimum. An alarm in the form of a dry contact relay closure shall provide an indication that this has occurred. Battery systems per NEC 70 shall have a disconnect switch or breaker to remove a battery from the rest of the DC power system. A battery charger/eliminator alarm and monitor panel is shown in Figure 5-8, Battery Alarm and Monitor Panel.

FIGURE 5-5. TYPICAL RCF POWER DISTRIBUTION DIAGRAM

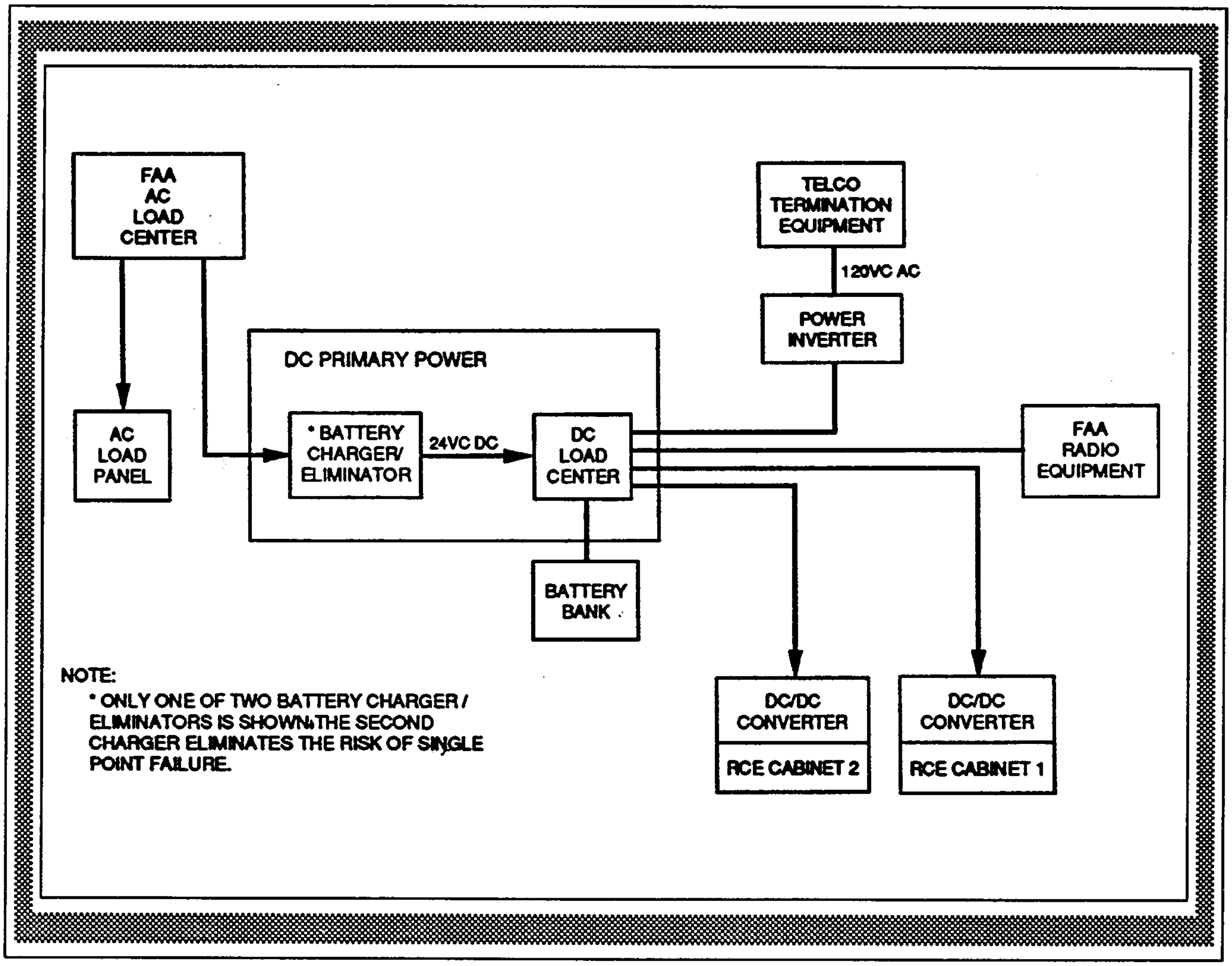


FIGURE 5-6. TYPICAL DC POWER RACK

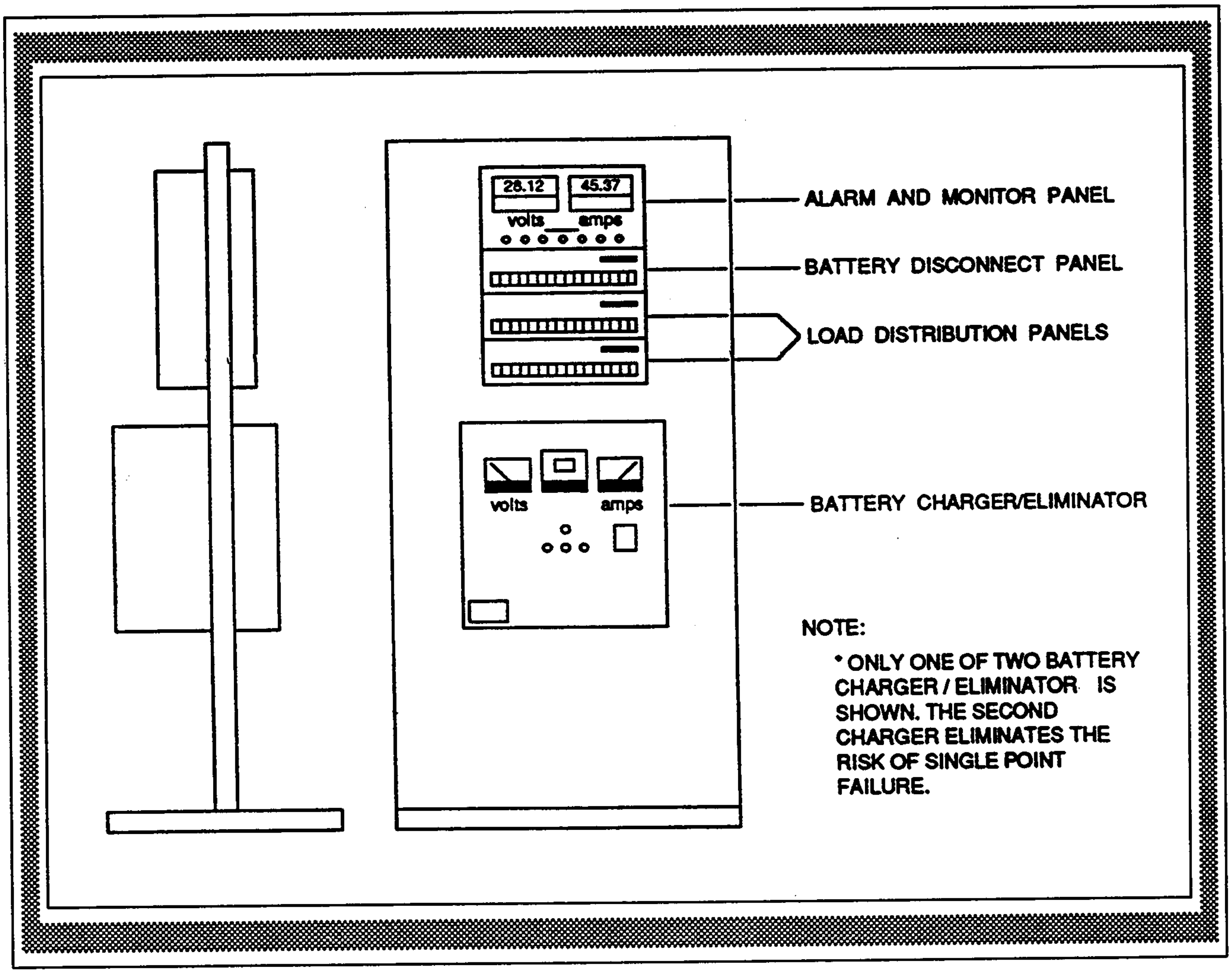


FIGURE 5-7. TYPICAL DC LOAD DISTRIBUTION

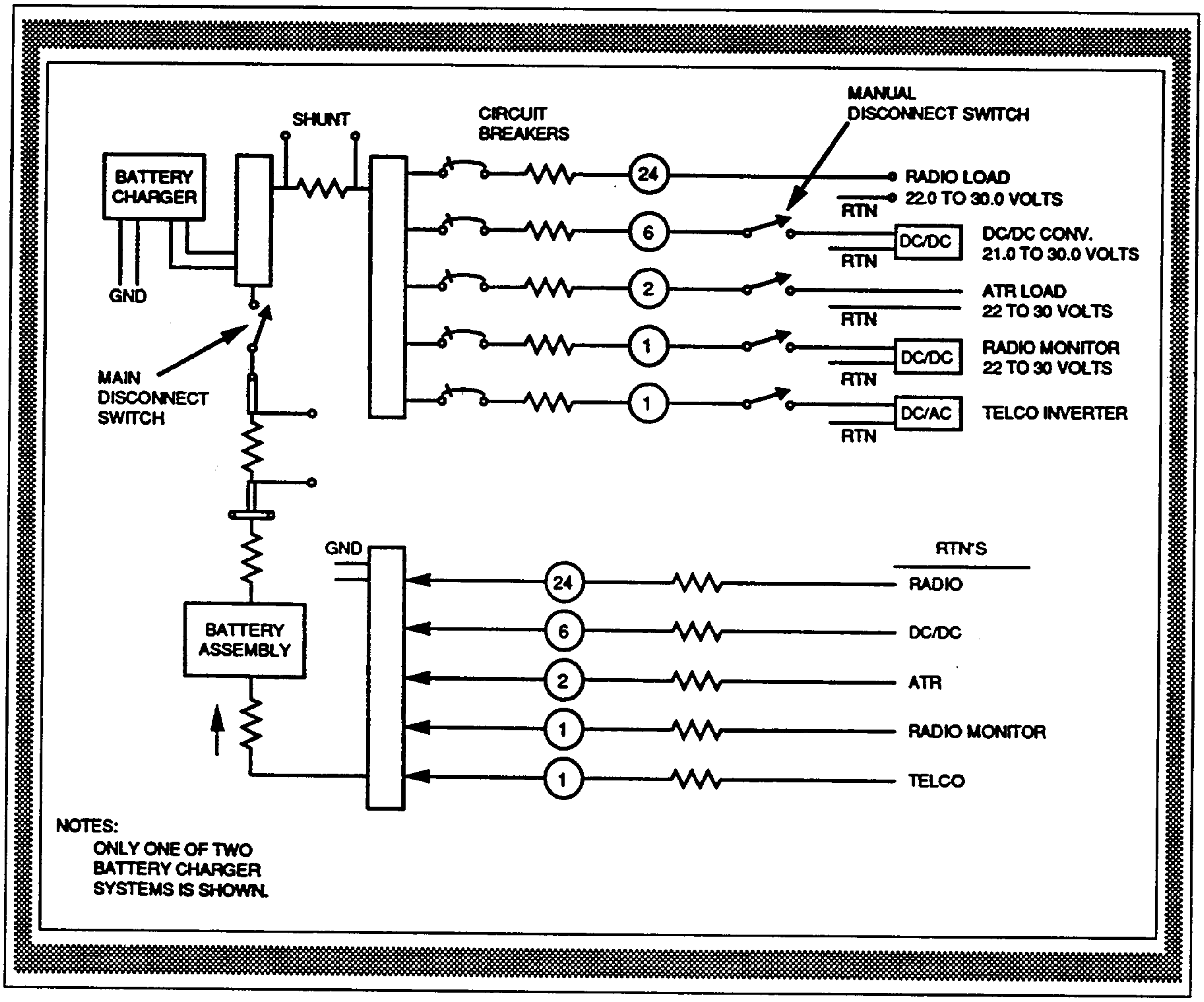
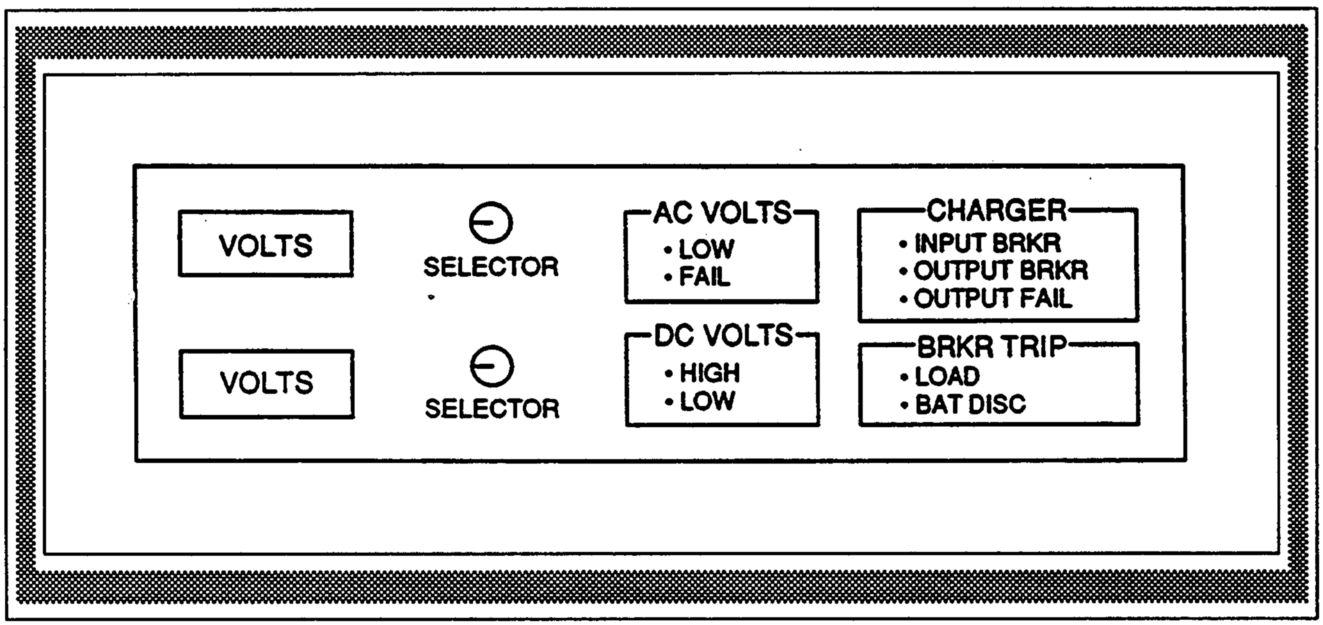


FIGURE 5-8. BATTERY ALARM AND MONITOR PANEL



d. **Distribution Panel**. The load distribution panel shall provide a housing to mount and connect the circuit breakers. These breakers shall provide protection for radio equipment, DC to AC inverters, antenna transfer relays, and radio monitoring equipment. A dedicated circuit breaker shall be used for each piece of equipment.

e. **Battery Charger**. Battery chargers shall be mounted in the DC power rack. They are to correspond to expected load requirements for 3-channel, 6-channel, and 12-channel site applications. Each charger shall be capable of concurrently servicing the RCF peripheral, radios, battery float or recharge, and a DC to AC inverter. Batteries are float charged to 2.25 volts (V) per cell.

f. **Batteries**. Batteries shall be used to provide a backup DC power source. Sealed (Gel Cell) type batteries that require no special ventilation and have a 10-year life expectancy shall be used. A minimum of 4 hours of battery backup operation is required at RCF installations. Other sites may require more backup operating time and shall be installed as required.

148. **GROUNDING REQUIREMENTS**. Battery chargers shall be grounded to the multipoint ground system.

NOTE: DO NOT CONNECT the negative side of ANY battery to the facility ground system!

149. **DC WIRING**. A feed and return wire shall be used for each piece of equipment. Color coding for the DC distribution wiring shall be red for positive voltage and black for negative. A No. 10 AWG or larger copper wire shall always be used and enclosed in ferrous conduit. The wires shall also be twisted together a minimum of eight turns per foot.

150. **DC POWER-UP PROCEDURES**. Perform power-up procedures after the AC power wiring and the DC distribution wiring have been completed.

a. **Charge Batteries**. Close the battery safety switch. This permits the DC output of the batteries to charge the capacitors. If the initial surge current trips the safety switch, reset and close the switch. It will take one to two minutes for the batteries to charge the capacitors to 89 percent of the battery terminal float voltage. When the voltage reaches 85 percent, close the DC power supply output circuit breakers and reset the power supply in accordance with the instruction manual.

b. **Adjust Power Supply**. Close the power supply AC input circuit breakers. Adjust power supply voltages to meet system requirements. Procedures for this adjustment are found in the equipment instruction manual. Charge the battery system until the charging current stabilizes for 3 hours. Adjust the power supply for the recommended float voltage of 2.25 to 2.28 volts for each cell.

151.-155. **RESERVED**.

CHAPTER 6. EQUIPMENT INSTALLATION

SECTION 1. SYSTEM DESCRIPTION

156. **GENERAL**. This section describes the various system configurations and hardware requirements for the installation of A/G Communications Equipment at typical RCF's.

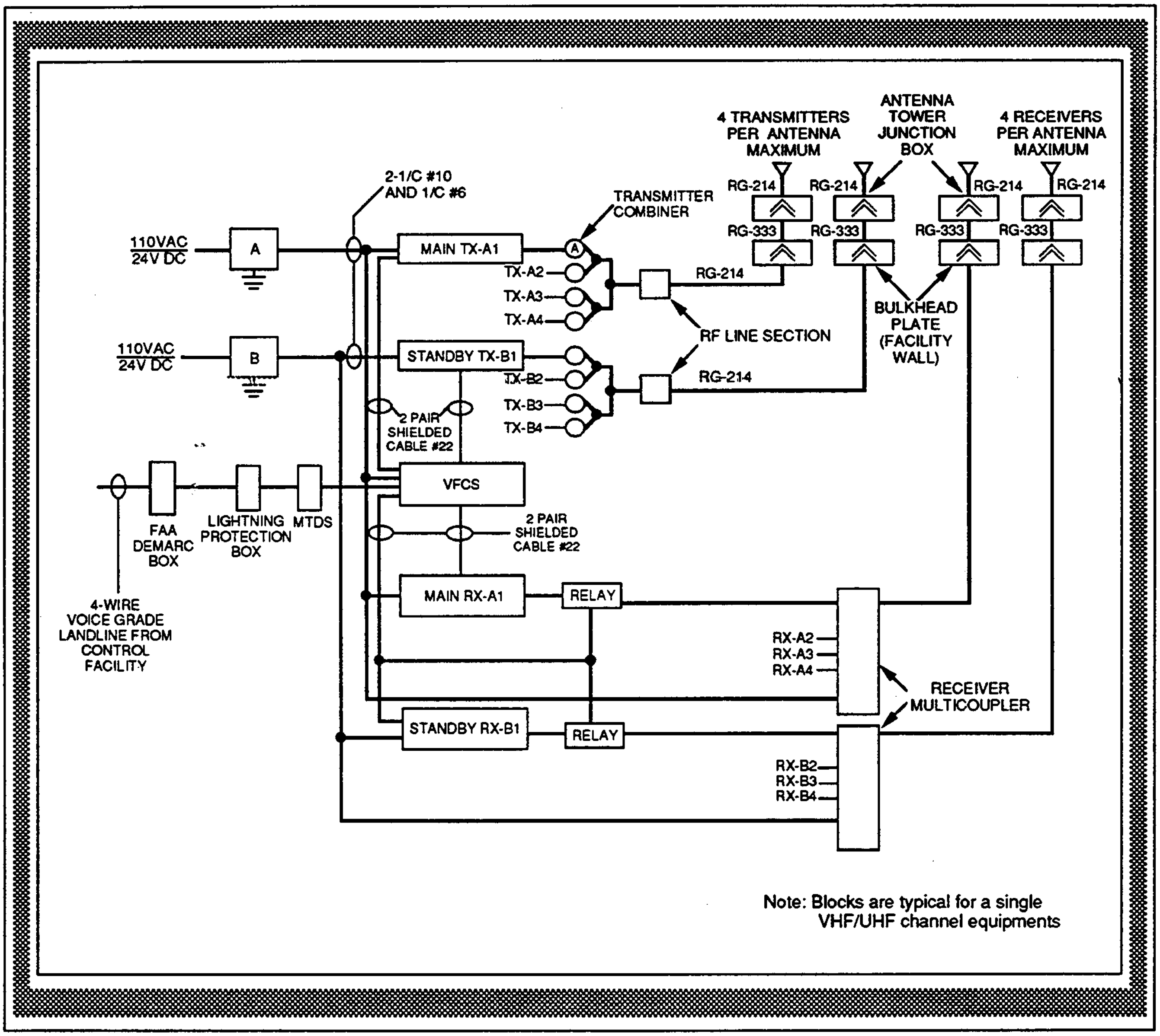
a. **Requirements**. Installation requirements concerning rack configurations for transmitters, transmitter combiners, receivers, receiver multicouplers, transmitter/receiver (T/R) configurations, control interface units, wire ducts, cable trays, terminal wiring, and antenna systems are also addressed. Proper equipment installation at an RCF will improve radio communications system performance.

b. **System Configuration Description**. The following system configuration generally describes installation of ARTCC RCF A/G equipment. New design changes are incorporated that may differ substantially from previous designs. Operational applications for Airport Traffic Control Tower (ATCT) and Automated Flight Service Center (AFSS) remote equipment may differ from the examples. A block diagram of typical RCF A/G equipment is shown in Figure 6-1, RCF Electronic Equipment Block Diagram.

(1) **Equipment Racks**. A typical RCF may have at least two rows of equipment racks. The standard and most common equipment rack is 83 inches in height with a depth of 22 inches (newer equipment racks may be 25 inches deep) and has the Electronic Industry Association (EIA) 19 inch equipment chassis panel width. This width results in an outside dimension of 21.75 inches for the rack. Other width and depth dimensions may be used to satisfy site requirements. The configuration of equipment in the rack shall allow for frequency expansion and prevention of interference between and away from existing facility equipment.

(2) **Transmitters**. An RCF site may be equipped with a complement of single frequency RF transmitter units to support the number of operational channels required by the facility. Transmitters shall be assigned in single channel equipment groups. Each channel contains up to four transmitter units. Two Transmitter (TX) units are provided for the assigned VHF (one main and one standby equipment). Two TX units may be provided for the assigned UHF, one main and one standby unit. Both VHF and UHF main transmitters may at the same time contain the same channel audio when active. The standby transmitter unit is remotely switched-in as a backup for a malfunctioning a unit on a one-for-one basis.

FIGURE 6-1. RCF ELECTRONIC EQUIPMENT BLOCK DIAGRAM



(3) **Receivers**. An RCF site may be equipped with a complement of single frequency RF receiver units to support the number of operational channels required by the facility. Receivers shall be assigned in single channel equipment groups. Each channel is supported with up to four receiver units. Two radios are supplied for the assigned VHF frequency (one main and one standby unit) and two radios may be supplied for the assigned UHF frequency (one main and one standby unit). Both VHF and UHF main receiver equipment audio may be active at the same time. Standby receiver equipment is remotely switched-in on a one-for-one basis.

(4) **Transmitter Combiners**. In accordance with current FAA philosophy, no more than four transmitters shall be connected to a combiner system assigned to one antenna. The effect of combiner insertion loss on system performance shall be considered when using these devices. Main and standby transmitters SHALL NOT be connected to the same combiner, and the combiner system shall have an insertion loss of approximately 2.5 dB or less.

(5) **Receiver Multicouplers**. In accordance with current FAA philosophy, no more than four receivers shall be connected to a multicoupler assigned to one antenna. The multicoupler shall have a gain adjust so that its insertion loss is no more than 0 dB.

(6) **Linear Power Amplifier**. Linear Power Amplifiers (LPA) are used to increase A/G radio range to meet air traffic coverage requirements. Strict attention to site management guidelines is required when using these devices so that intermodulation and interference to other equipment does not occur. The use of low loss RF cable and high gain antennas shall be considered as alternate methods of satisfying A/G radio communications coverage requirements.

(7) **Voice Frequency Control System Equipment**. The Voice Frequency Control System (VFCS) interface equipment provides a method to control several radio functions from a distant location for each channel of equipment. The current system provides control tones over voice audio using the same wire pair. Transmit audio is conveyed over a wire pair separate from the receive audio wire pair.

(8) **RF Line Section Panel**. The RF line section panel is considered as a standard part of each site antenna system. Therefore, each transmit antenna system shall have an RF line section within its system. RF line sections provide a method to measure transmitter output power and provide a method to establish the antenna Voltage Standing Wave Ratio (VSWR). This method indicates the capability of the connected antenna system to radiate most of its input energy. Receiving antenna systems may also be tested for their VSWR condition using an RF line section.

(9) <u>RF Cable Transfer Relay Panel</u>. Main or standby connection of a transmitter or receiver to an antenna may be provided by the use of an RF cable transfer relay panel. This panel enables the remote switchover of transmitters, receivers and LPA amplifiers. Sites that contain transmitter combiners will not require a transfer relay panel to do the transmitter transfer function.

(10) <u>Landline Termination</u>. Incoming telephone lines shall terminate in an Federal Aviation Administration (FAA) demarc box or FAA/TELCO mini-demarc system provided with an attached surge arrester lightning protection box. All landlines shall pass through this enclosure before connection to VFCS equipment.

157. **<u>EQUIPMENT RACK CONFIGURATION</u>**. This paragraph describes the typical rack configurations located within the host facility shelter. Refer to figure 6-2 through figure 6-6, which illustrate typical equipment rack configurations.

a. <u>Single Channel RF Equipment Rack</u>. A single channel RF rack normally contains paired VHF/UHF main and standby transmitters as well as VHF/UHF main and standby receivers. Normally, frequency A is VHF and frequency B is UHF. This rack is shown as the TX/RX Layout in Figure 6-2, Typical Single Channel Equipment Racks.

b. <u>Transmitter Equipment Rack</u>. A transmitter rack contains one to eight transmitters for main and standby operation. An RF line section or coaxial transfer relay panel shall be located at the top of the rack or as required. This configuration is shown as the TX Only Layout in Figure 6-3, Typical Two Channel Equipment Racks, and is formed in a two rack combination for two channels. Multiple combinations of this rack pair shall be used to achieve the channel quantity required.

c. <u>Transmitter Combiner Equipment Rack</u>. Transmitter combiner racks may be open or closed type. A typical rack accommodates up to eight VHF RF cavities. The transmitter combiner rack shall be located adjacent to, or near, the transmitter rack to minimize the RF cable length between the transmitter output and the combiner input. In some configurations, a cavity filter is required to further suppress interference. This cavity filter is similar in appearance to a combiner cavity. The UHF combiner configuration uses two cavities per transmitter port since isolators are too restrictive in bandwidth to cover potential changes. The combiner rack configurations for VHF and UHF are illustrated in Figure 6-4, Typical Transmitter Combiner Equipment Racks.

FIGURE 6-2. TYPICAL SINGLE CHANNEL EQUIPMENT RACKS

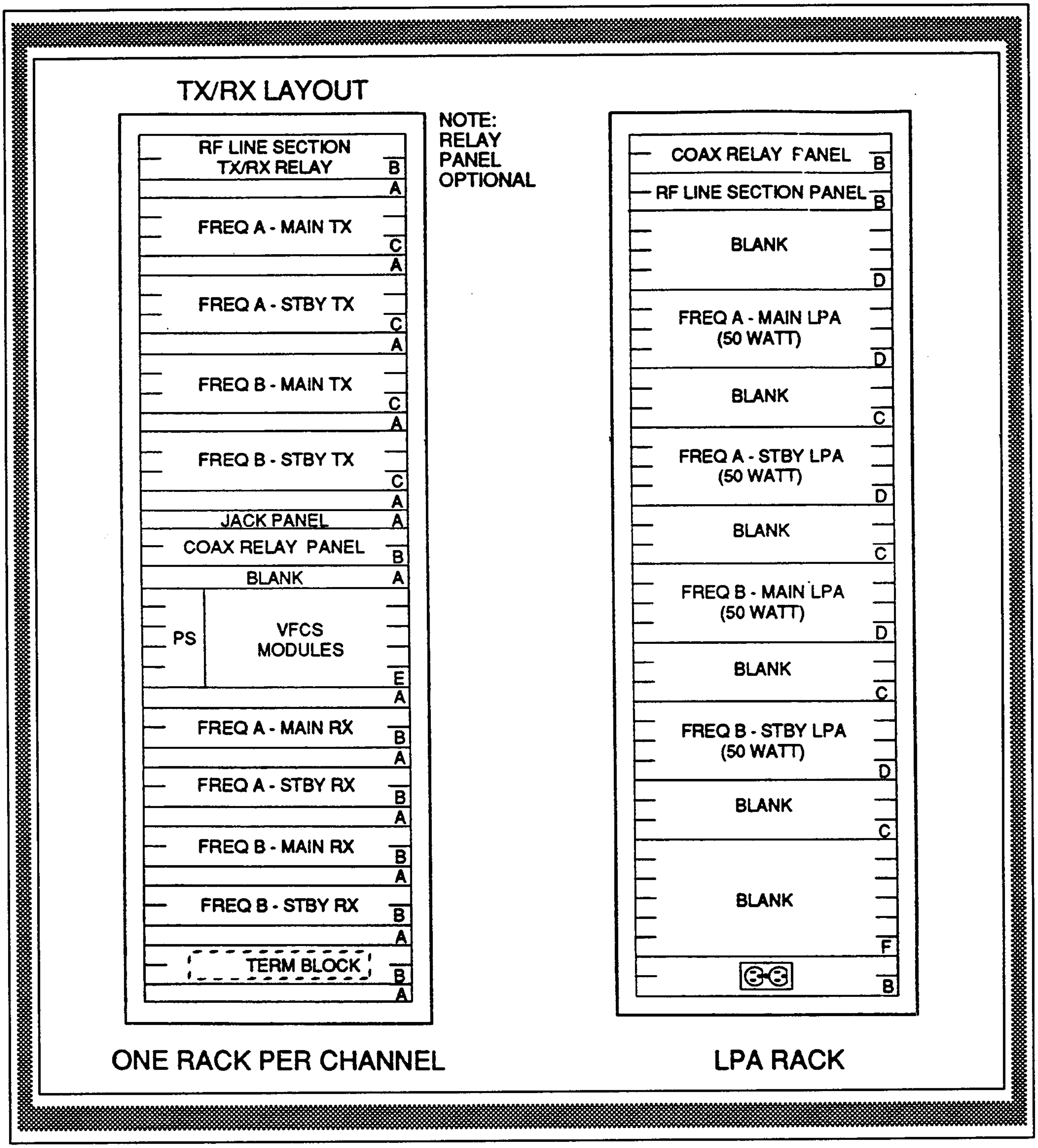


FIGURE 6-3. TYPICAL TWO CHANNEL EQUIPMENT RACKS

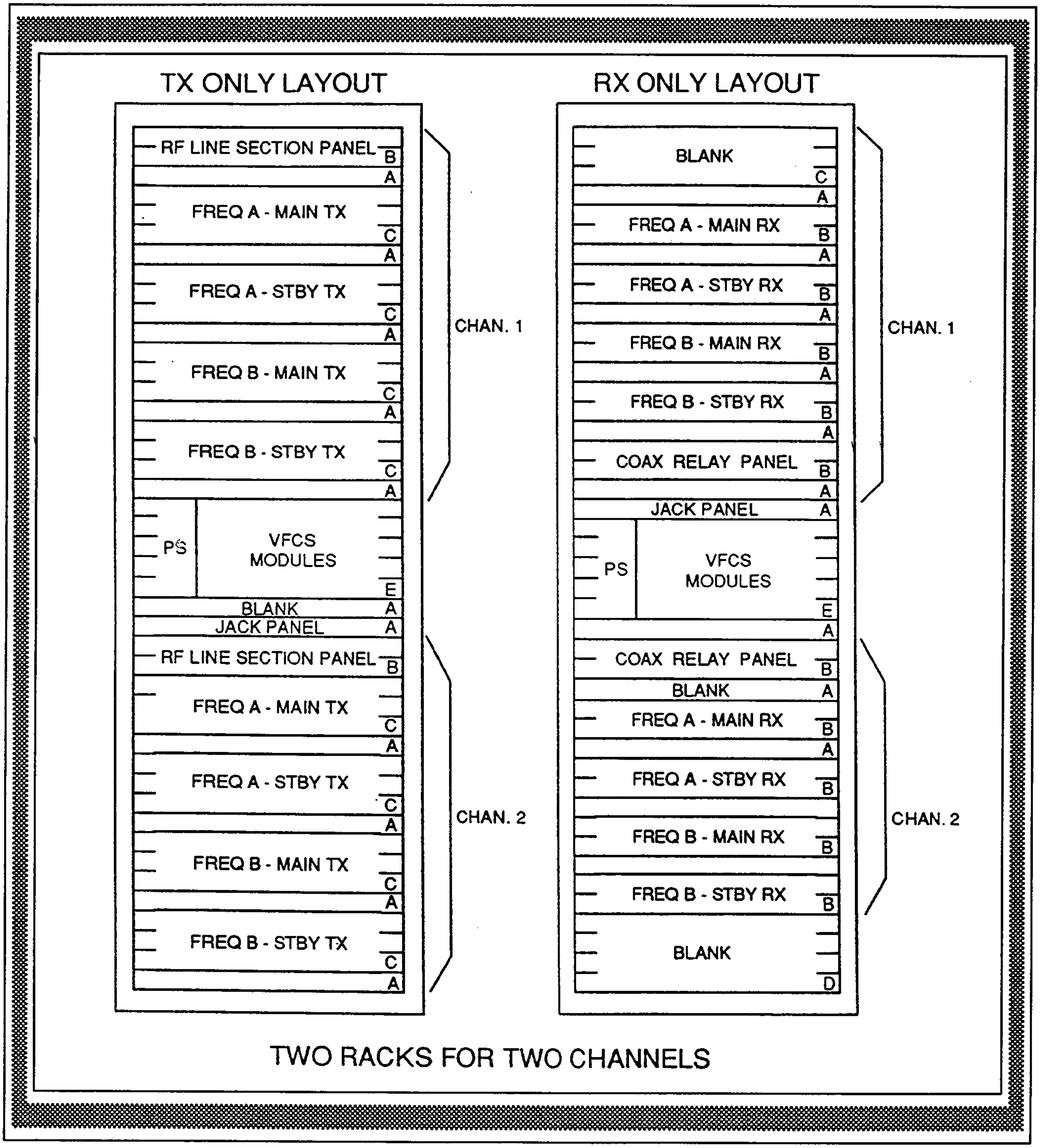
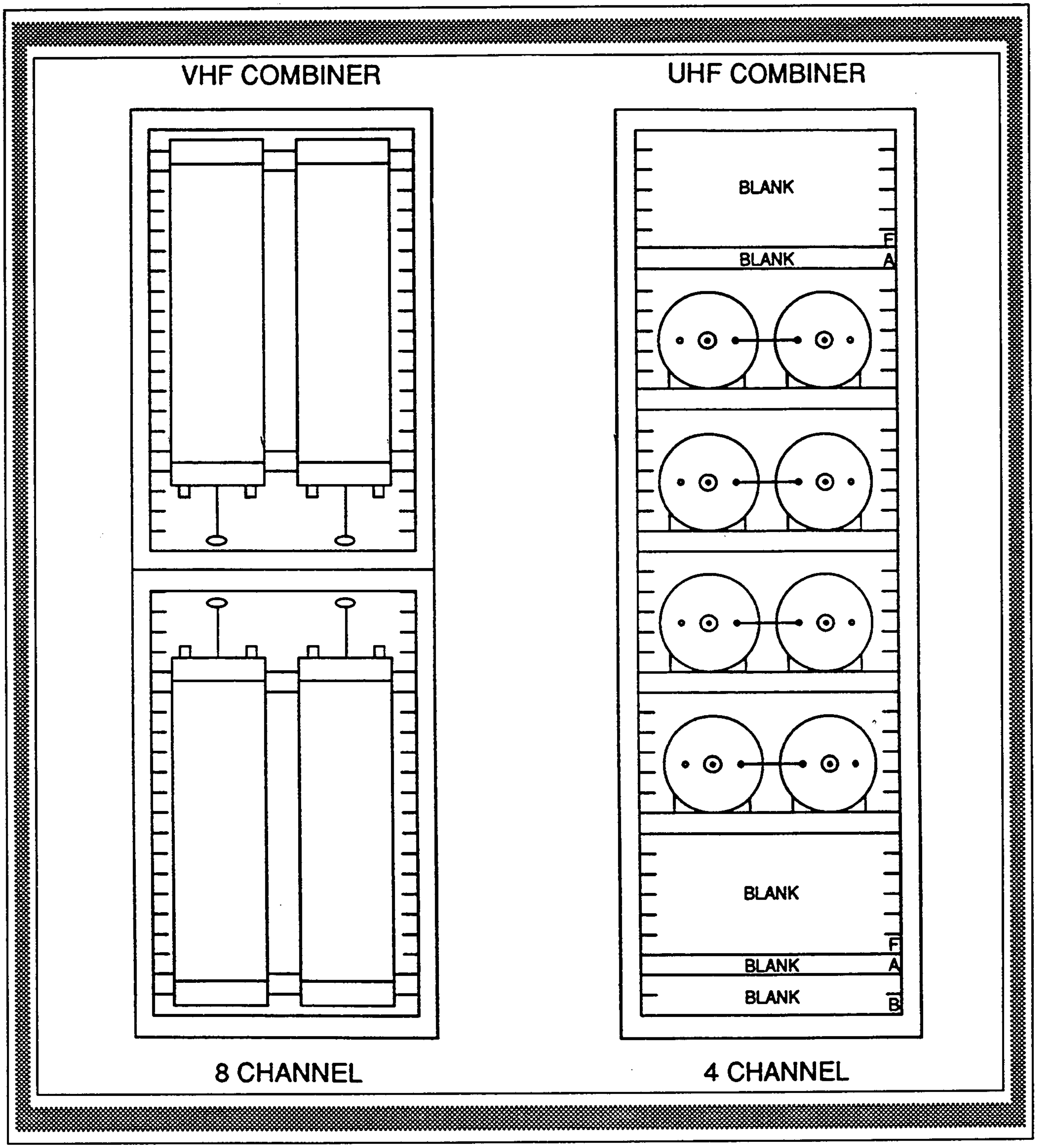


FIGURE 6-4. TYPICAL TRANSMITTER COMBINER EQUIPMENT RACKS



d. **Linear Power Amplifier Equipment Rack**. An LPA equipment rack typically contains four amplifiers (associated with a single channel equipment rack). The present LPA is only available for use with AC power. This rack configuration is shown as the LPA Rack in figure 6-2. The LPA equipment is used in those RCF locations in which additional coverage range is needed to support site communications requirements.

e. **Receiver Equipment Rack**. A receiver equipment rack may contain one to eight receivers for main and standby operation. In multichannel configurations the receiver rack may be separate from the transmitter rack. This receiver equipment rack configuration is shown as the RX Only Layout in figure 6-3.

f. **Multicoupler Equipment Rack**. A receiver multicoupler equipment rack may contain one to eight multicouplers per rack for both main and standby operation. In most installations, locate the multicoupler in the top section of the receiver rack. In larger systems an alternate method is used. The multicoupler is mounted in a separate rack positioned as close as possible to the receiver rack it supports. This method is used when space in the receiver rack does not allow for multicoupler installation. The length of RF cable between the receivers and their respective multicouplers shall be kept as short as possible. Multicoupler units are required to support the two channels as shown in the configuration, RX Only Layout, shown in figure 6-3. An eight channel multicoupler configuration is shown in Figure 6-5, Receiver Multicoupler Equipment Rack.

g. **Voice Frequency Control System Equipment Rack**. The VFCS equipment may be mounted in a separate individual rack or integrated into an RF equipment rack. There are several physical forms for VFCS equipment dictated mainly by the number of channels supported. In sites with many channels to control, a separate radio control rack is used such as that shown in Figure 6-6, Voice Frequency Control Equipment Rack. In cases as shown in figure 6-2 and figure 6-3, the VFCS equipment is installed in the same rack and may be one or more A panels in height. The VFCS equipment is classified as low frequency equipment requiring a separate single point ground connection.

158. **WIREWAYS**. Metallic square duct, conduit and a cable tray system shall be installed in the RCF equipment room. Support is provided for cable and wire runs between the equipment racks, the AC panelboard, the grounding system, and the antenna bulkhead panel. Figures 6-7, Typical RCF Cable Tray Installation, Top View and Figure 6-8, Typical RCF Metallic Duct, Cable Tray and Conduit Installation, illustrate a typical installation. Figure 6-8 includes the various elements and elevations of the cable support system. Specific site requirements will determine the actual configuration.

FIGURE 6-5. RECEIVER MULTICOUPLER EQUIPMENT RACK

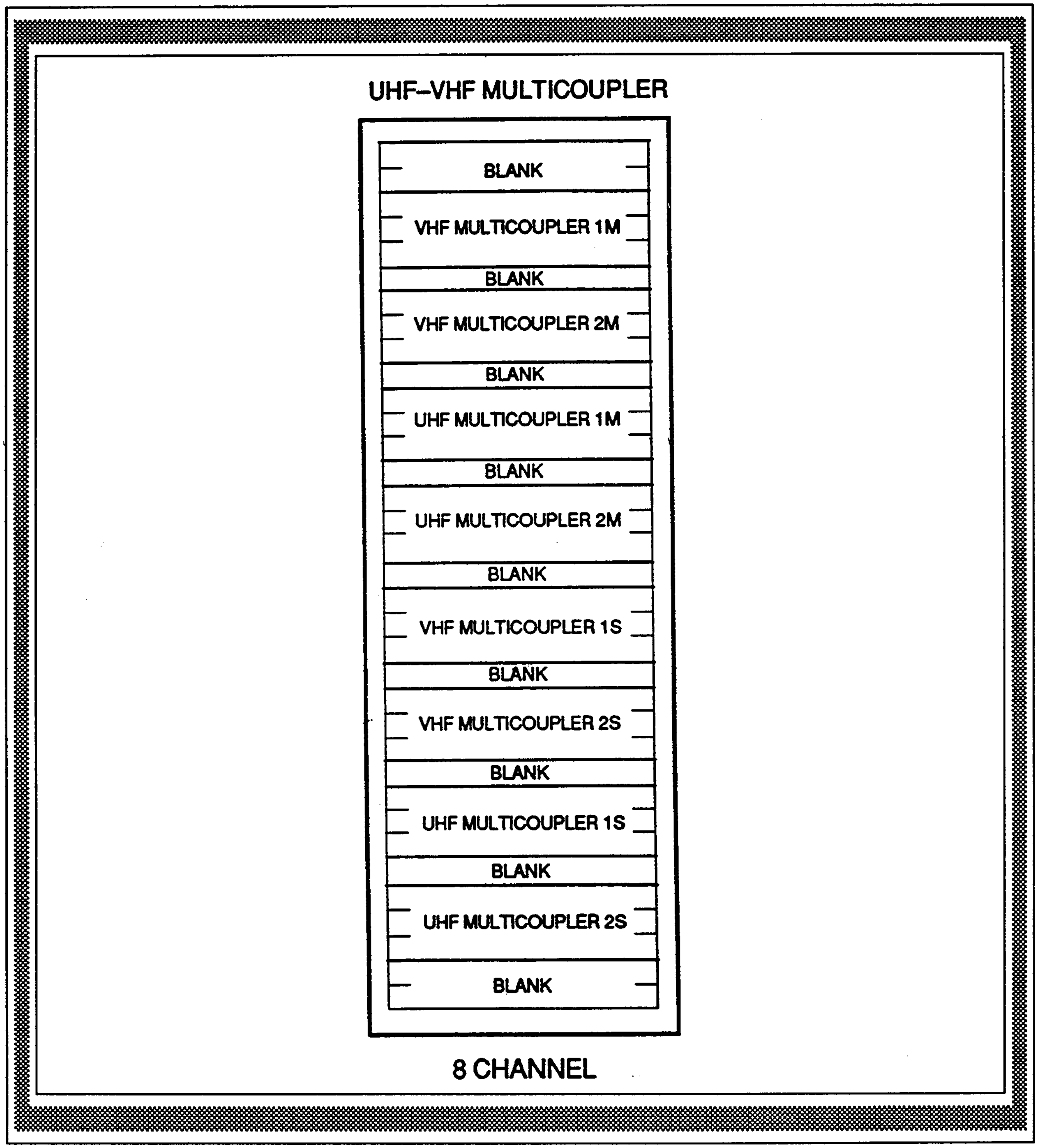


FIGURE 6-6. VOICE FREQUENCY CONTROL EQUIPMENT RACK

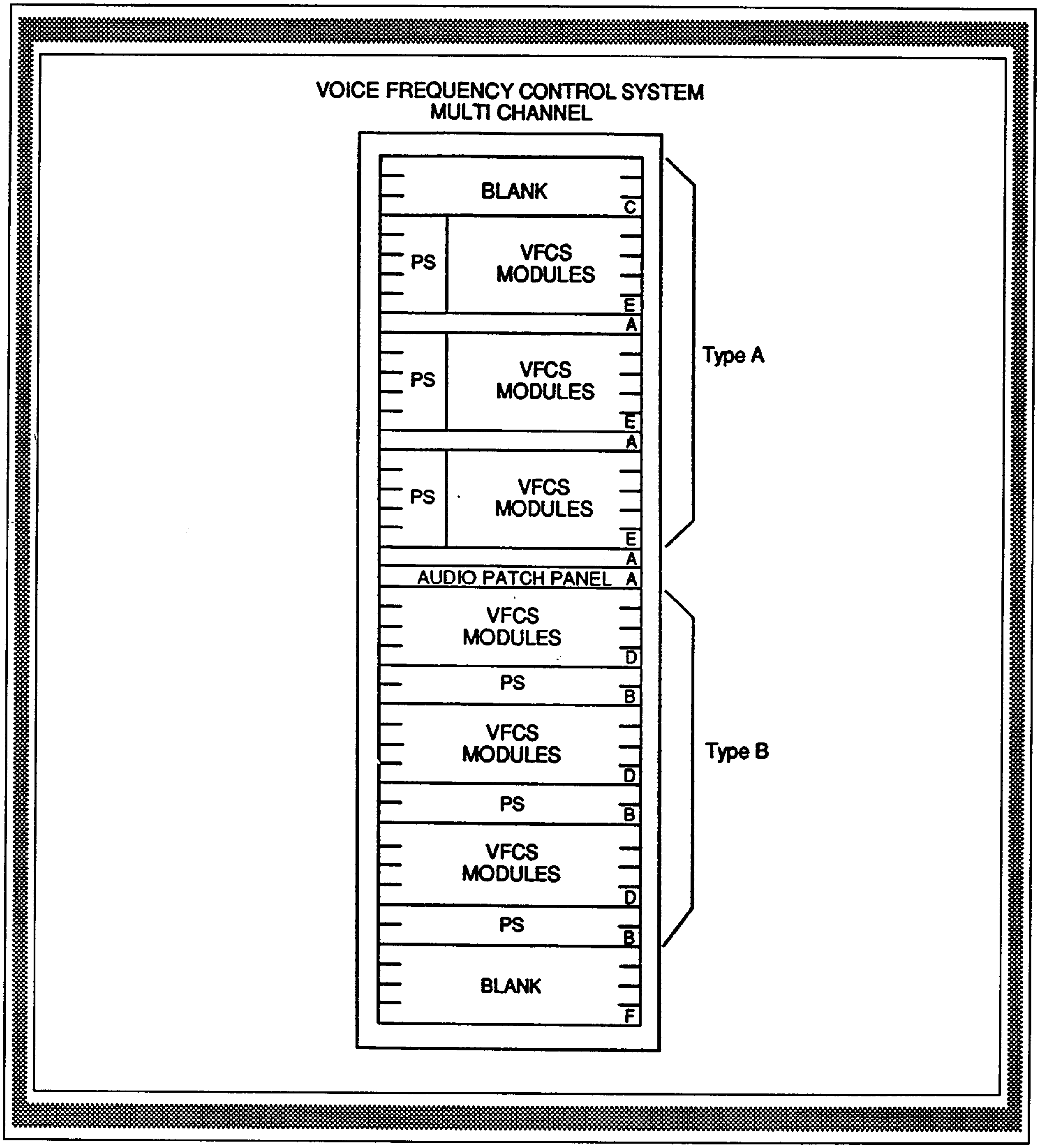


FIGURE 6-7. TYPICAL RCF CABLE TRAY INSTALLATION, TOP VIEW

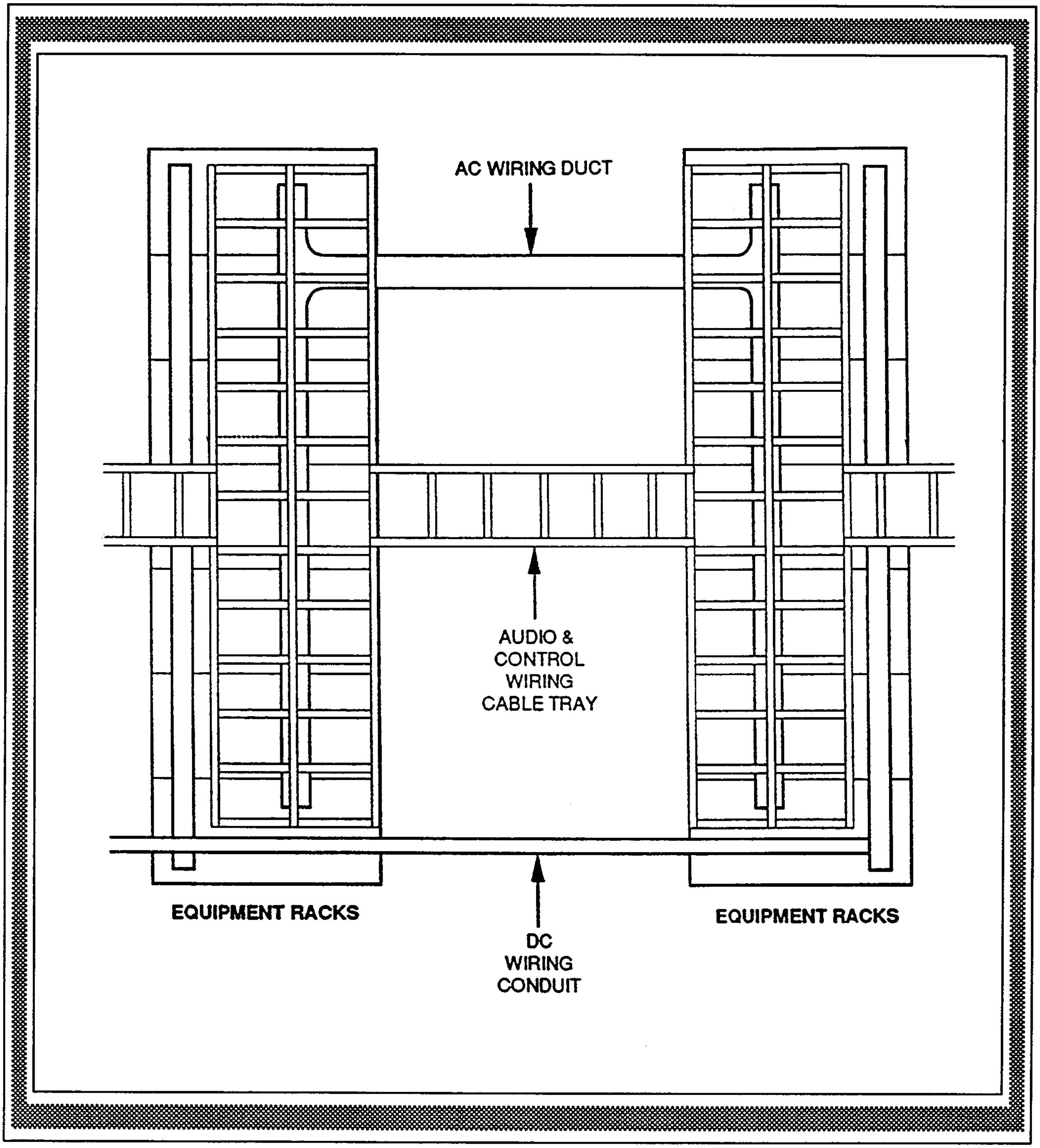
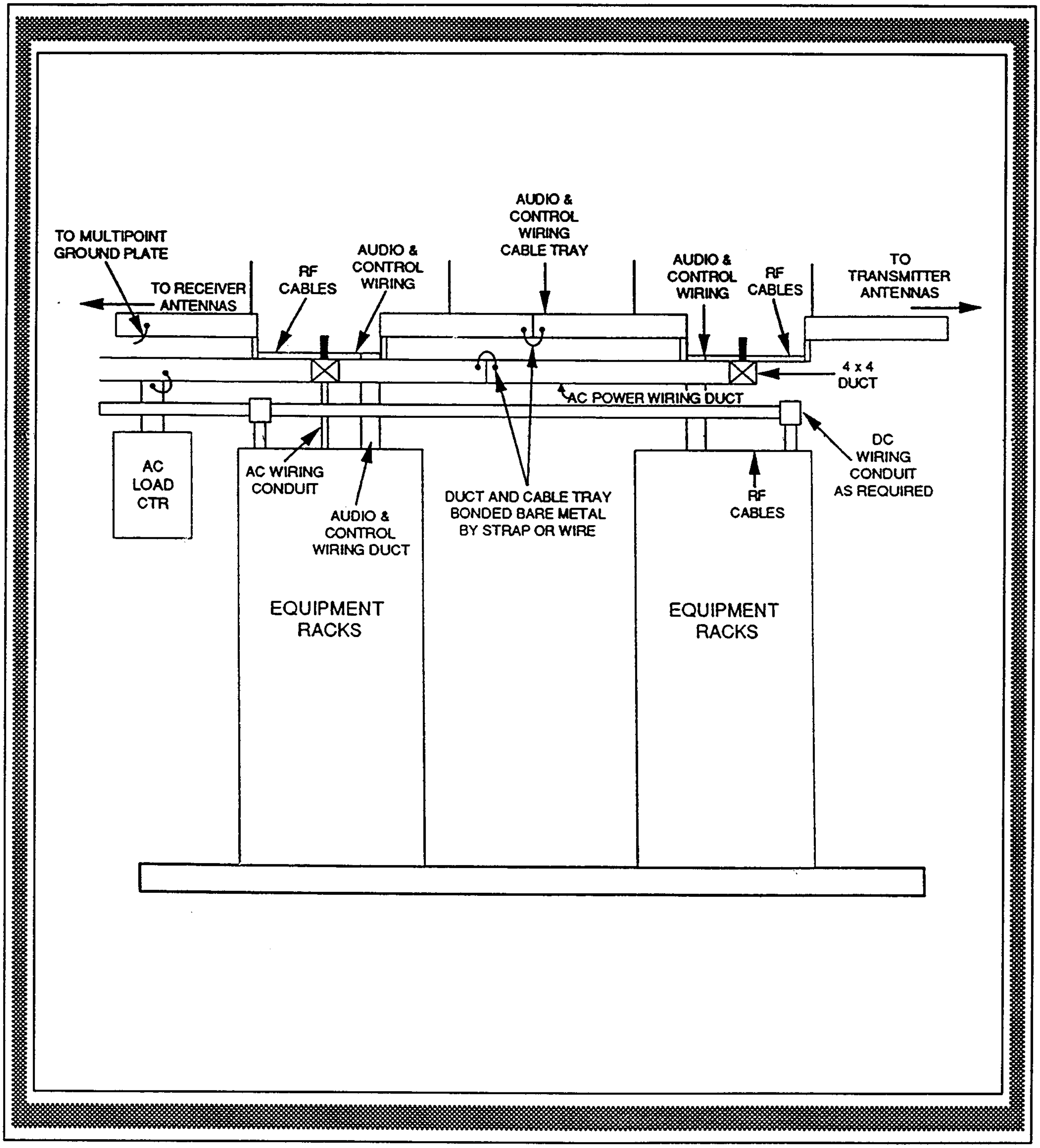


FIGURE 6-8. TYPICAL RCF METALLIC DUCT, CABLE TRAY AND CONDUIT INSTALLATION



All duct and cable tray sections shall be bonded bare metal to bare metal by strap or copper wire. Conduit sections are bonded by the conduit locking nuts. All metal cable supports shall be connected to the site multipoint grounding system.

a. **Cable Tray**. Cable trays shall be installed to provide mechanical support and protection for cable runs. Cable trays provided with metallic barriers for separating and shielding cables shall be used. Cabling installed in the trays are DC power cabling, transmitter output cabling, receiver input cabling, audio cabling and control cabling. Transmitter and DC power cabling shall be separated from receiver and audio/control cabling.

b. **Metallic Duct**. Metallic ducts or conduit shall be installed above the equipment racks for the AC power cabling. The type of ducts used shall be determined after consideration of the EMI and EMC shielding requirements.

c. **Conduit**. Conduit shall be selected to satisfy the environmental conditions and EMI/EMC protection requirements. Refer to FAA-C-1217e, Electrical Work, Interior, for guidance. The recommended conduit, ferrous Electrical Metallic Tubing (EMT), shall be installed to provide mechanical support and protection to the wire runs. PVC shall only be used underground or encased in concrete. The size of the conduit used shall be selected to permit easy cable installation. High pulling tensions and chafing may cause damage to the cable during installation when conduit bends are too sharp or if the conduit is sized too small for the cable size being installed. A pulling compound shall be used to reduce friction and avoid potential cable damage when pulling cable through conduit. The lubricant selected shall be compatible with the cable jacket.

(1) **EMT Conduit**. EMT thin wall metallic conduit shall only be used for interior installations where rust and oxidization are minimal. EMT conduit provides EMI and EMC protection. The most common application for EMT conduit is protection of AC power wiring for facility lighting, heating/cooling systems, convenience outlets and AC wiring to equipment racks as required. EMT conduit is also recommended for audio cable routing.

(2) **PVC Conduit**. Both heavy wall semi-rigid and flexible PVC conduits may be used for exterior installations. PVC conduit may be installed underground or encased in concrete to provide mechanical support and protection to cable runs when EMI and EMC protection is not required.

159.-162. **RESERVED**.

SECTION 2. INSTALLATION OF EQUIPMENT

163. **EQUIPMENT INSTALLATION**. The typical RCF A/G communications equipment is installed in the racks as follows:

a. **Transmitter Equipment**. Install the specified number of transmitters in the equipment rack with the correct hardware. The installation positioning is illustrated in figures 6-2 and 6-3. The transmitters shall be separated from each other by one `A' size (1.75") blank panel. The transmitters shall be installed using chassis slides. Mount the RF line section and/or main/standby (M/S) coaxial transfer relay panel at the top of the equipment rack.

b. **Transmitter Combiner Equipment**. No more than four transmitters shall be supported by a single antenna and combiner system. Each transmitter shall have one cavity (VHF) or two cavities (UHF) dedicated to it in the combiner assembly. The cavities (four) shall be tuned for minimum power loss on their assigned frequency and maximum isolation of adjacent frequencies. This is normally accomplished by the manufacturer prior to delivery. The output of individual cavities is connected with a cable harness to other cavity/transmitter combinations to a common point. This common point is then connected to a transmission line which feeds a single antenna. Cables used for the interconnection of cavities are cut to specific lengths determined by the frequencies of the transmitters to which they are connected. Paragraph 169c, Cavity Interconnect and Harness Cables, contains additional information on the cable harness.

(1) **Relay Configurations**. Several sites containing only a few channels will not require combiner equipment. These sites with three or fewer channels can use coaxial transfer relay panels to allow transfer from main transmitter equipment to standby transmitter equipment, the addition of a power amplifier, or operation of transmitters and receiver in the transceiver configuration. Subparagraph 169e, Transfer Relay Panel Cabling Configurations 1, 2, 3 and 4, contains additional information on cable configurations.

(2) **VHF and UHF Transmitter Combiner Racks**. A transmitter combiner rack may contain either VHF or UHF cavities. The VHF transmitter combiner cavity rack may accommodate eight cavities (eight channels) and operate between 118-137 MHz. The UHF transmitter combiner cavity rack may contain up to eight cavities (four channels) and operate between 225-400 MHz. The combiner may be broken into two ranges of 225-300 MHz and 300-400 MHz. Transmitter combiner configurations are shown in figure 6-4.

(3) **Combiner Installation**. The combiner cavities normally are installed in the rack supplied with the cavities. The racks can be open frame type or closed frame as illustrated in figure 6-4. The cavities shall be mounted in accordance with the manufacturer's instructions included with the rack. Hardware for mounting the cavities is supplied with the cavities. The rack shall be grounded to the multipoint ground plate.

c. **Receiver Equipment**. Install the required number of receivers in the equipment rack with appropriate hardware. The installation positioning is shown in figures 6-2 and 6-3. Receivers shall be separated from each other by one `A' size blank panel. The receivers shall be installed using chassis slides. Install main/standby coaxial transfer relay panels as required.

d. **Receiver Multicoupler Equipment**. The receiver multicouplers shall accommodate the main and standby VHF requirements of the 118-137 MHz frequency range and the UHF requirements of the 225-400 MHz frequency range. No more than four receivers shall be supported by a single antenna and multicoupler system. Multicouplers shall be separated from each other by one `A' size blank panel. The multicoupler shall be installed in the rack by attaching the multicoupler chassis slides to the rack. All unused receiver ports shall be terminated with a 50-ohm load. Each chassis shall be grounded to the rack multipoint ground bus bar.

(1) **VHF/UHF Receiver Multicoupler Racks**. A stand-alone receiver multicoupler rack shall contain both main and standby VHF and UHF multicouplers similar to the combination shown in figure 6-5. Other practical combinations with receiver equipment shall be determined by site configuration requirements. Main and standby VHF and UHF receivers shall not be connected to the same multicoupler. Referring to figure 6-3, four separate multicouplers would be required to support this one rack.

(2) **Multicoupler Installation**. The receiver multicouplers may be installed in the rack as shown in figure 6-5. The multicoupler equipment illustrated is for an eight channel application. The individual receiver multicoupler shall be connected to the multipoint equipment ground system. A jumper wire is connected to the equipment ground stud and to the rack equipment ground bus bar. An UL approved AC power cord shall provide a protection ground connection. Mounting hardware shall be used to secure the front panel of the multicoupler to the equipment rack.

164.-165. **RESERVED**.

SECTION 3. EQUIPMENT RACK WIRING AND CABLE INSTALLATION

166. **RACK TERMINAL BLOCK**. Each equipment rack shall be equipped with TELCO Type 66B3-50 terminal blocks or equivalent to permit relocation of racks or replacement of equipment without disturbing existing wiring. Terminal blocks shall be mounted on a baffle plate with a metallic cover. All signal and control wiring to and from equipment installed in an individual rack shall pass through the terminal blocks en route to or from other equipment units either internal or external to that rack.

167. **AUDIO AND CONTROL CABLES**. Audio and control cables may be installed in a cable tray, metallic duct or EMT conduit. The cables shall have an outer shield to minimize the adverse impact of EMI on the audio information or control signal information being routed over these cables. Audio and control signals shall be routed on separate cables. All cabling within the rack shall be neatly dressed, separating audio/control, RF coaxial cable and AC/DC wiring in a manner similar to that shown in Figure 6-9, Typical Equipment Rack Wiring, and Figure 6-11, Typical Rack Equipment Grounding.

a. **Landline Termination**. Landlines shall enter the RCF equipment room via an FAA demarcation box or FAA/TELCO demarc system equipped with appropriate surge protection devices. Shielded pair No. 22 AWG voice grade landlines shall be installed via a metallic duct or conduit from the landline lightning protection circuit to the VFCS equipment rack terminal block. Landline cabling entering and leaving the demarcation box shall be terminated in a manner similar to that shown in Figure 6-10, Typical Landline Cable Termination. Refer to paragraph 123, Landline Protection, for additional illustrations.

(1) **Landline Distribution Configuration**. Landline audio/ control cables shall enter the communications equipment racks and terminate at an input terminal block (TELCO type 66B or equal). The terminal block shall have a full metallic enclosure mounted so that the case is grounded to the rack frame serving as an electrostatic shield. These audio/control cables shall be shielded pairs until they arrive at the VFCS equipment chassis. The shields for wire pairs shall be treated in the manner shown in figure 6-10. The output cabling for the VFCS shall also terminate at the input terminal block before continuing to the radio transmitter and receiver equipment. Cabling to the radio equipment shall be shielded pairs from the terminal block to the radios. Their shields shall be connected to the rack single point ground bus bar at the terminal block. As an option, an audio patch panel may be placed in this audio path. Special care must be taken to preserve the shield continuance. Figure 6-12, Typical Audio/Control Cable Configuration, illustrates

FIGURE 6-9. TYPICAL EQUIPMENT RACK WIRING

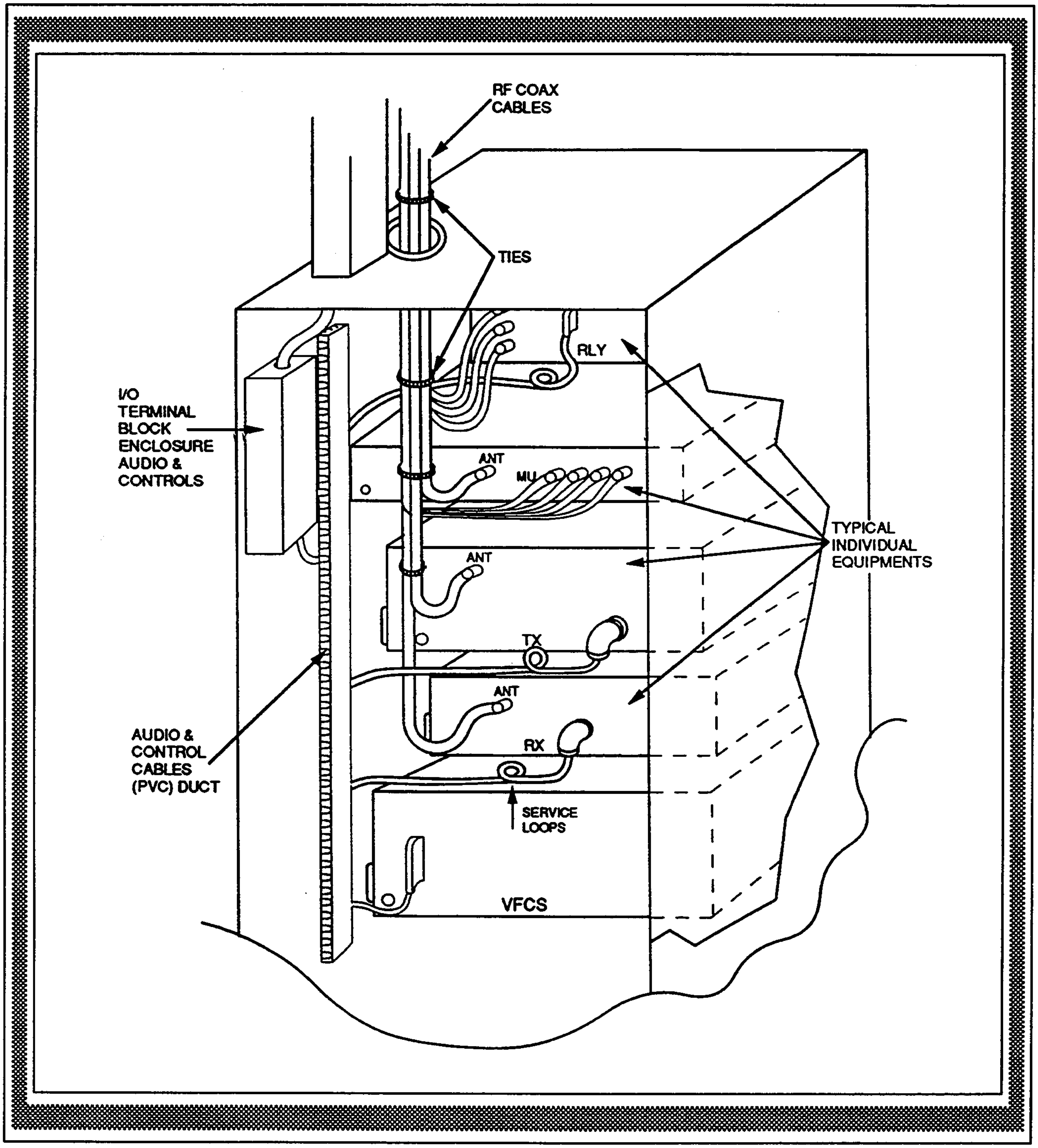


FIGURE 6-10a. TYPICAL LANDLINE CABLE TERMINATION

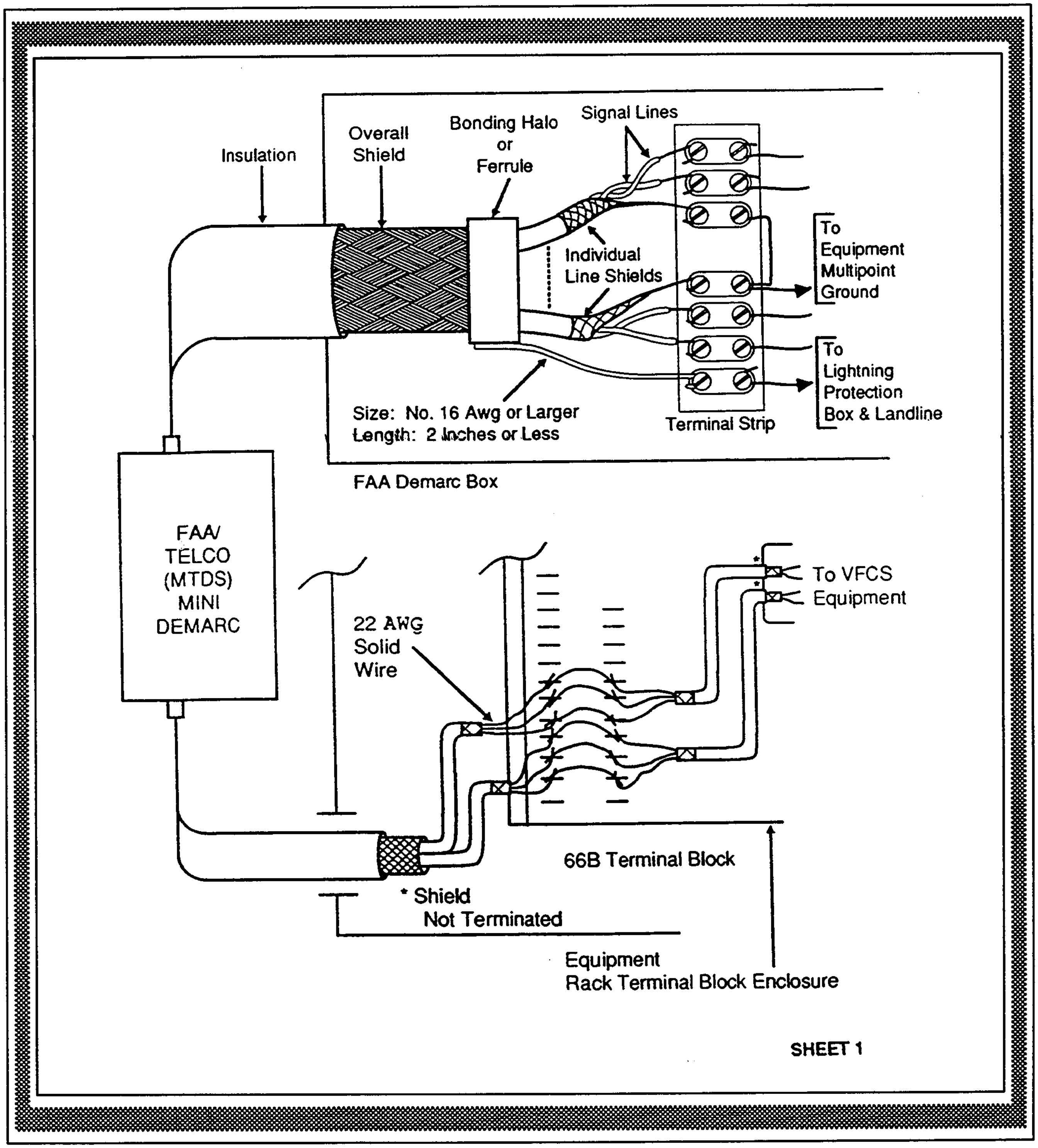
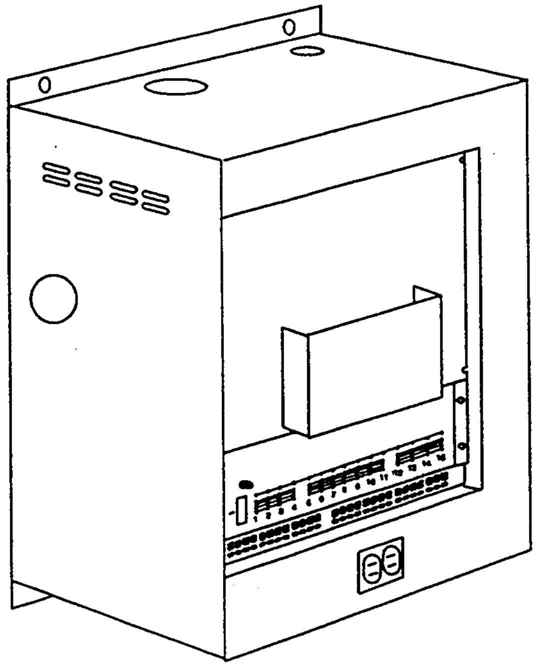


FIGURE 6-10b. TYPICAL LANDLINE CABLE TERMINATION



TYPICAL 12-CIRCUIT MTDS CONFIGURATION

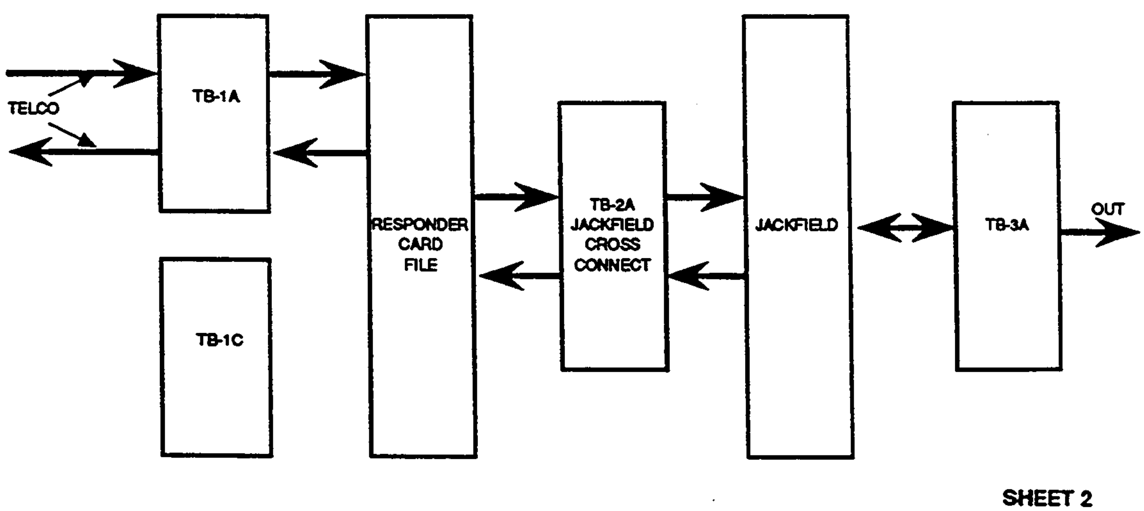


FIGURE 6-11. TYPICAL RACK EQUIPMENT GROUNDING

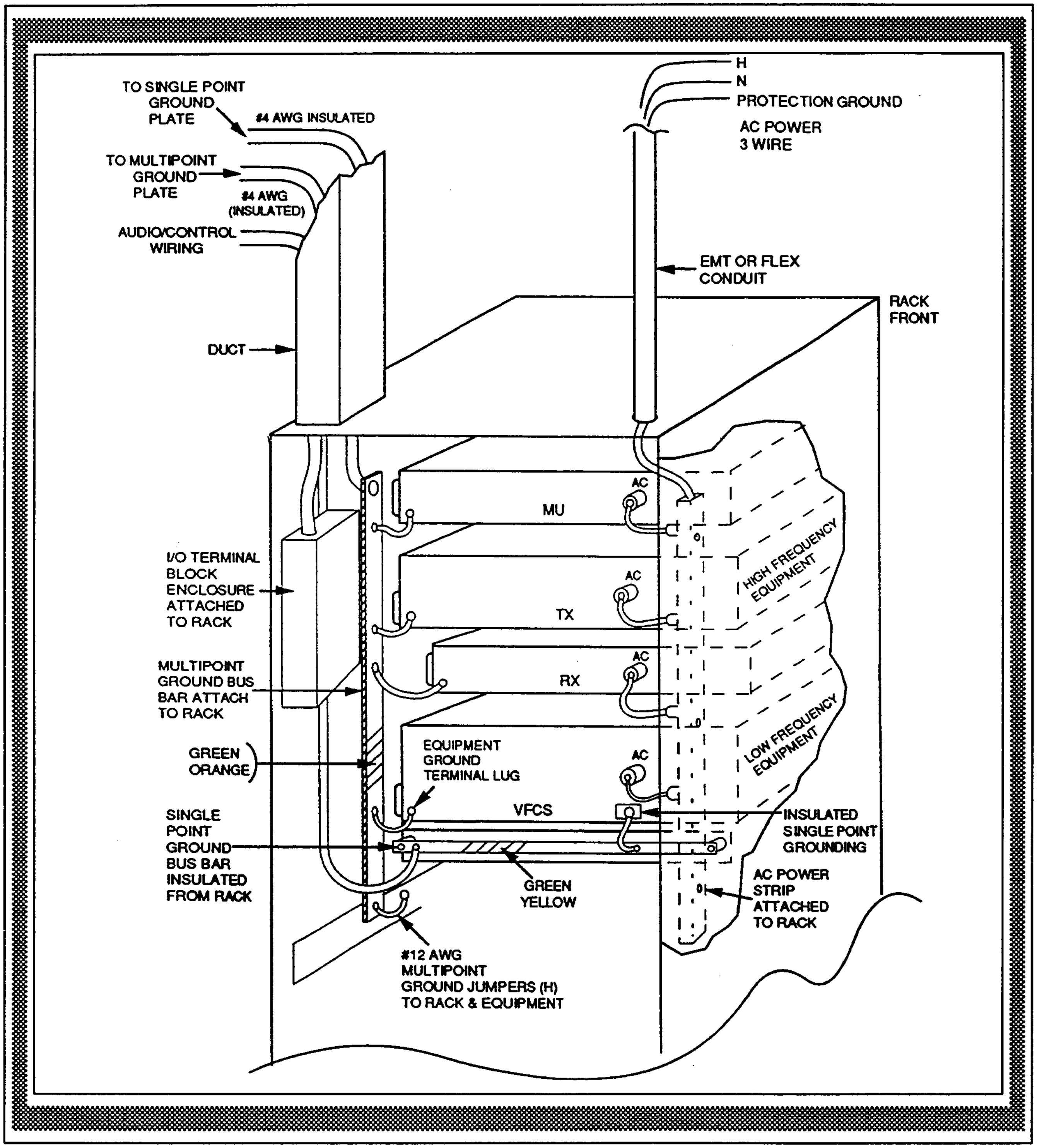
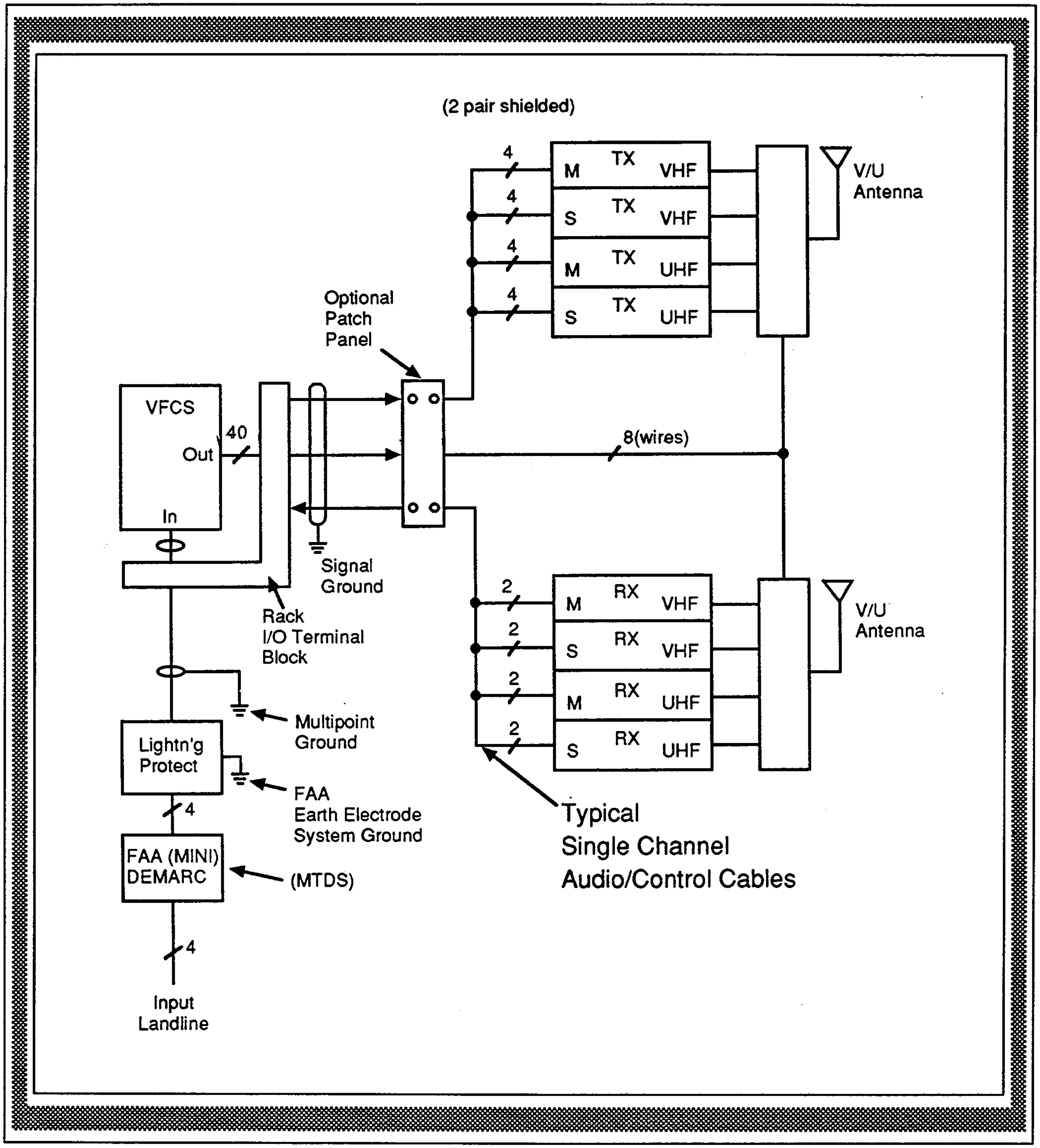


FIGURE 6-12. TYPICAL AUDIO/CONTROL CABLE CONFIGURATION



the application of this audio cabling method. Larger channel capacities will require more cabling and terminal blocks but the same general plan shall be maintained.

b. **Inter-rack Cabling**. The inter-rack audio/control cables shall be terminated at each of the designated rack terminal block(s). The inter-rack cables shall be installed along the left rear side to the top of the rack(s), as viewed from the rear. See figure 6-9 for wiring reference. Audio and control inter-rack wiring shall be routed through metallic ducts or cable trays and shall be routed separate from all power cables. The inter-rack RF cables shall be routed through an access opening in the top of the rack, through metallic duct or cable tray and separated in a similar manner.

c. **Equipment Grounding**. All equipment within an equipment rack shall have an electrical connection to the site multipoint grounding system. Each interior equipment shall have a separate connection to the rack multipoint copper bus bar ground. The bus bar shall be connected to the rack frame through a metal-to-metal mechanical connection or through a separate wire jumper loop. The bus bar shall also be connected to a nearby multipoint ground plate with a No. 4 AWG or larger copper wire. The AC power cord shall provide a separate protection ground along with power wiring as shown in figure 6-11.

168. **COAXIAL CABLE**. There are four general types of Military (MIL) specification RF coaxial cables that may be used at RCF sites. Cable characteristics for the four types of coaxial cables are listed in the following chart:

Type	Impedance	Attenuation (dB/100-Ft) 100 MH	Attenuation (dB/100-Ft) 400 MHz	Outside Diameter (Inches)	Cable Weight lb/ft
RG-214	50 Ohms	2.2 dB	4.6 dB	0.425	0.126
RG-223	50 Ohms	4.3 dB	8.8 dB	0.216	0.034
RG-331	50 Ohms	0.85 dB	1.9 dB	0.6	0.187
RG-333	50 Ohms	0.65 dB	1.4 dB	1.015	0.548

a. **Double Shielded RG-214 Coaxial Cable**. Double shielded RG-214 coaxial cables are used for all transmitter frequency combiner harnesses and general interior interconnection cable because of improved shielding characteristics and better mechanical flexibility. If an internal cable run is more than 25 feet, a lower loss cable such as RG-331 shall be used.

b. <u>Double Shielded RG-223 Coaxial Cable</u>. This type of coaxial cable has a smaller diameter and is more suitable for limited use in short run lengths. This type of coaxial cable should only be used as a last resort since it has high loss. The most common application of the cable is between the receiver input and the output of the receiver multicoupler. It is important that lengths used be as short as possible. These coaxial cables require a minimum bending radius of five times their cable diameter. The correct connector type shall be used on the cable end connected (without adapters) to equipment ports.

c. <u>RG-333/331 Coaxial Cable</u>. Low-loss, solid-sheath RG-333 coaxial cable shall be installed in all outside cable runs of more than 50 feet and, where practical, within the building. Low-loss, solid-sheath RG-331 coaxial cable may be used in short runs of 50 feet or less where it is impractical to install the larger more rigid RG-333 cable. The major restriction in using large diameter cables within the building is cable bend radius. Ensure that the cable bend radius is greater than 10 times the outer diameter of the cable. Inspect all cable at an RCF for handling or shipping damage before installation.

NOTE: Higher than recommended pulling forces, scraping forces around bends or edges, and accidental impact and other mechanical stresses can damage the cable during installation.

d. <u>Alternate Coaxial Cables</u>. An alternate coaxial cable type must be used in some applications because of high cable attenuation. For example, an air filled coaxial cable may be selected such as Heliax. Selecting this type of cable must be justified since costs are higher.

e. <u>Coaxial Cable Connectors</u>. RF coaxial cable connectors used on RG-214 and RG-223 coaxial cables shall be non-tarnish nickel-plated brass. RG-331 and RG-333 coaxial cable connectors shall be anodized aluminum and the contacts silver-plated. Figures 6-13, Typical Transmitter RF Cabling System, and 6-14, Typical Receiver RF Cable System block diagrams illustrate the coaxial cables and associated connectors. Table 6-1, Antenna System Materials List, gives common connector types and their part numbers.

169. **<u>RF COAXIAL CABLE INSTALLATION</u>**. All RF coaxial cables shall be supported with cautiously installed (not over tensioned) and finished (squarely cut off with no sharp edge) mechanical strap or tie wrap. Supports are used to prevent chafing and stress to RF connectors and cables. All RF cables shall be neatly dressed within the racks, separate from AC power or audio/control cabling. All spare or not-in-use coaxial cables shall be terminated in a resistive load type RF connector.

FIGURE 6-13a. TYPICAL TRANSMITTER RF CABLING SYSTEM (WITH COMBINER)

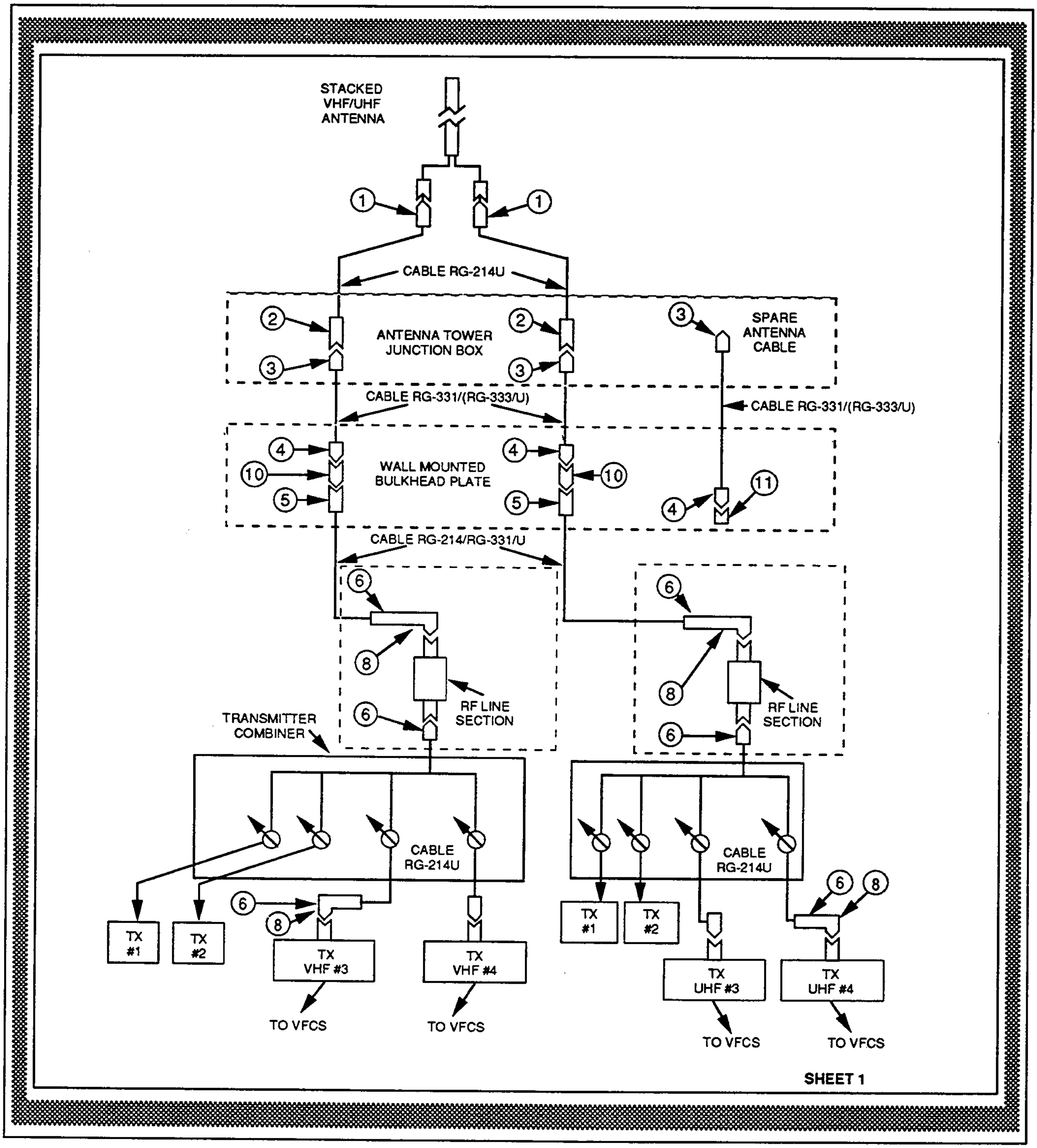


FIGURE 6-13b. TYPICAL TRANSMITTER RF CABLING SYSTEM (WITHOUT COMBINER)

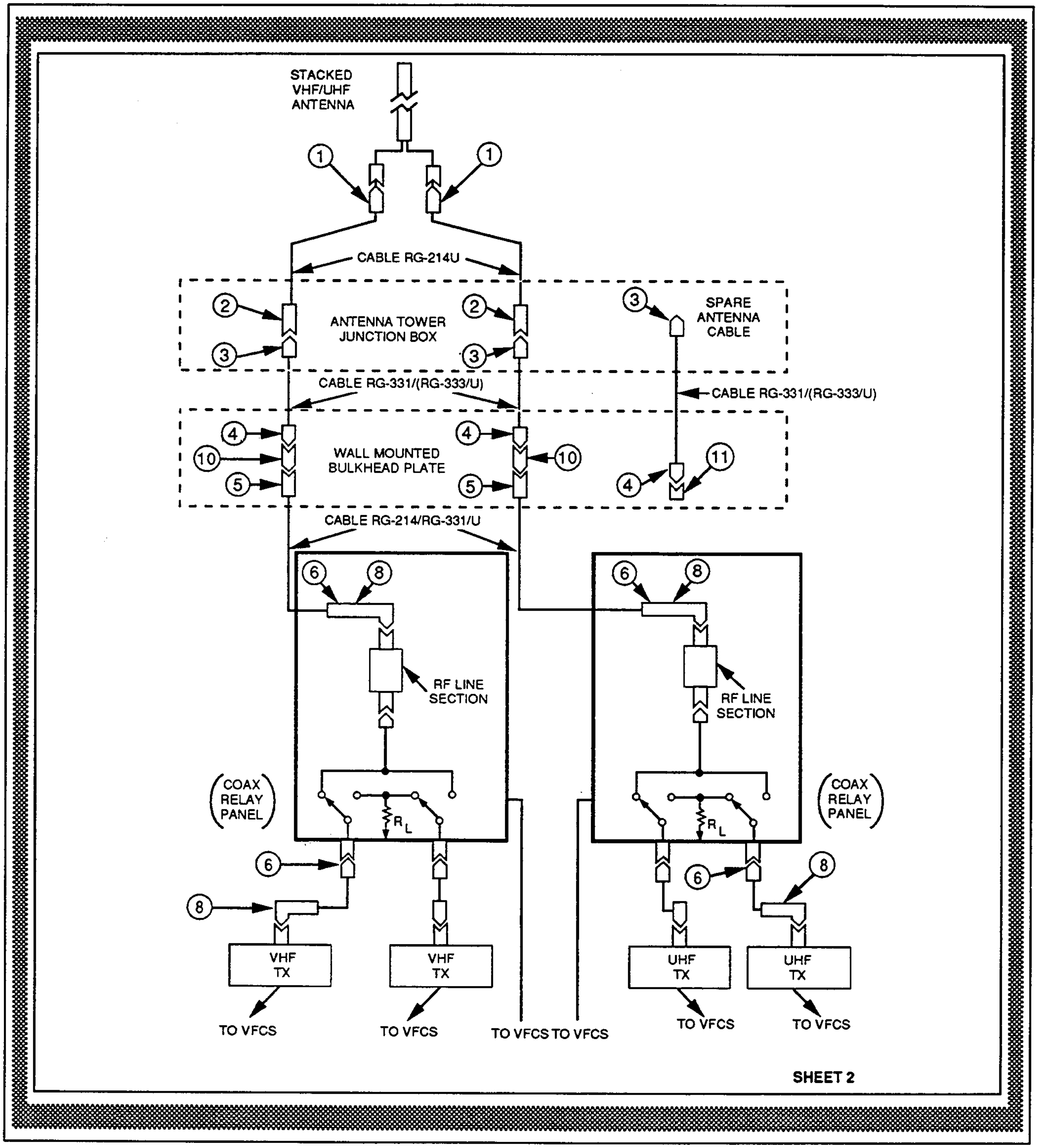


FIGURE 6-14a. TYPICAL RECEIVER RF CABLING SYSTEM (WITH MULTICOUPLER)

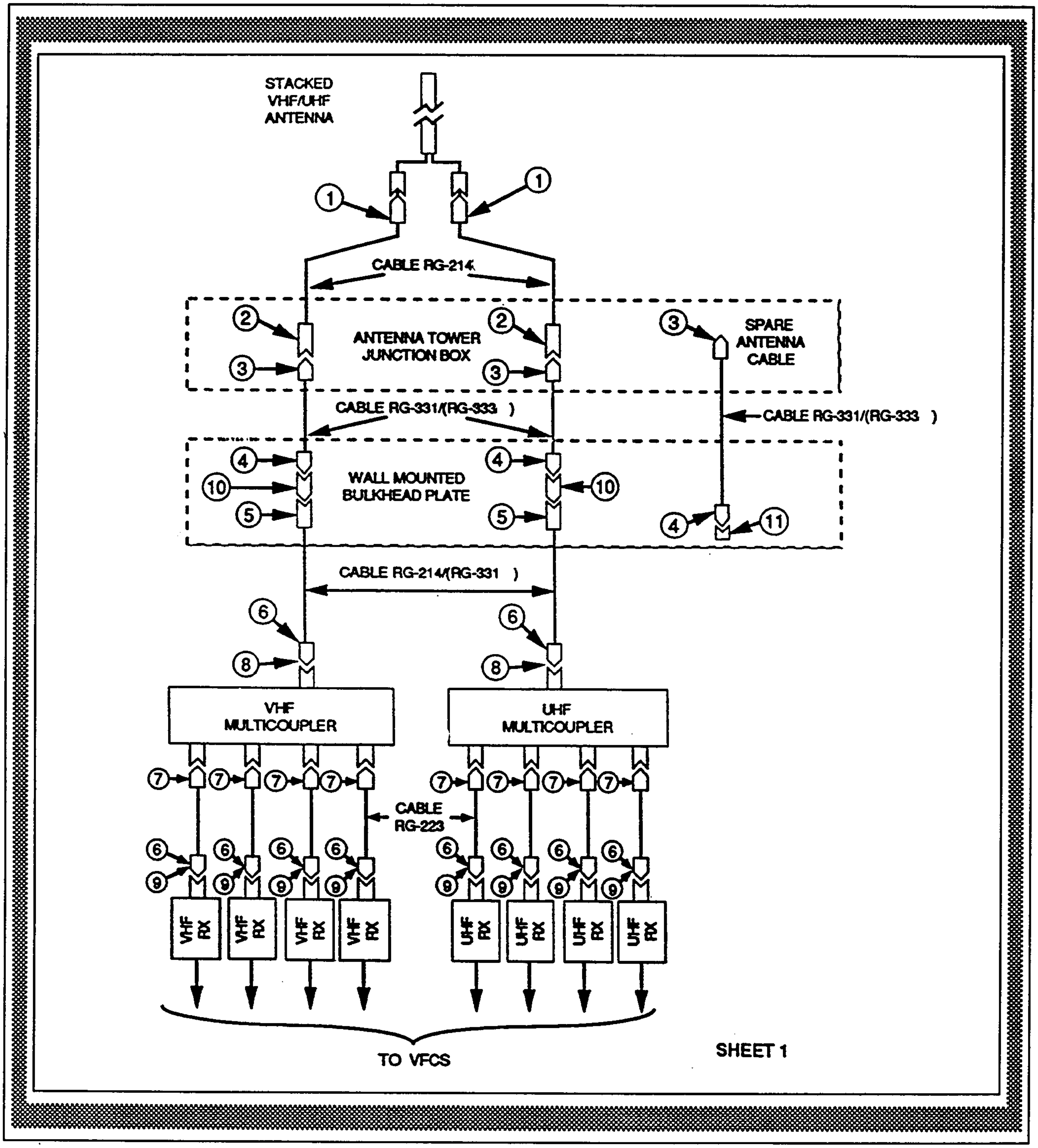


FIGURE 6-14b. TYPICAL RECEIVER RF CABLING SYSTEM (WITHOUT MULTICOUPLER)

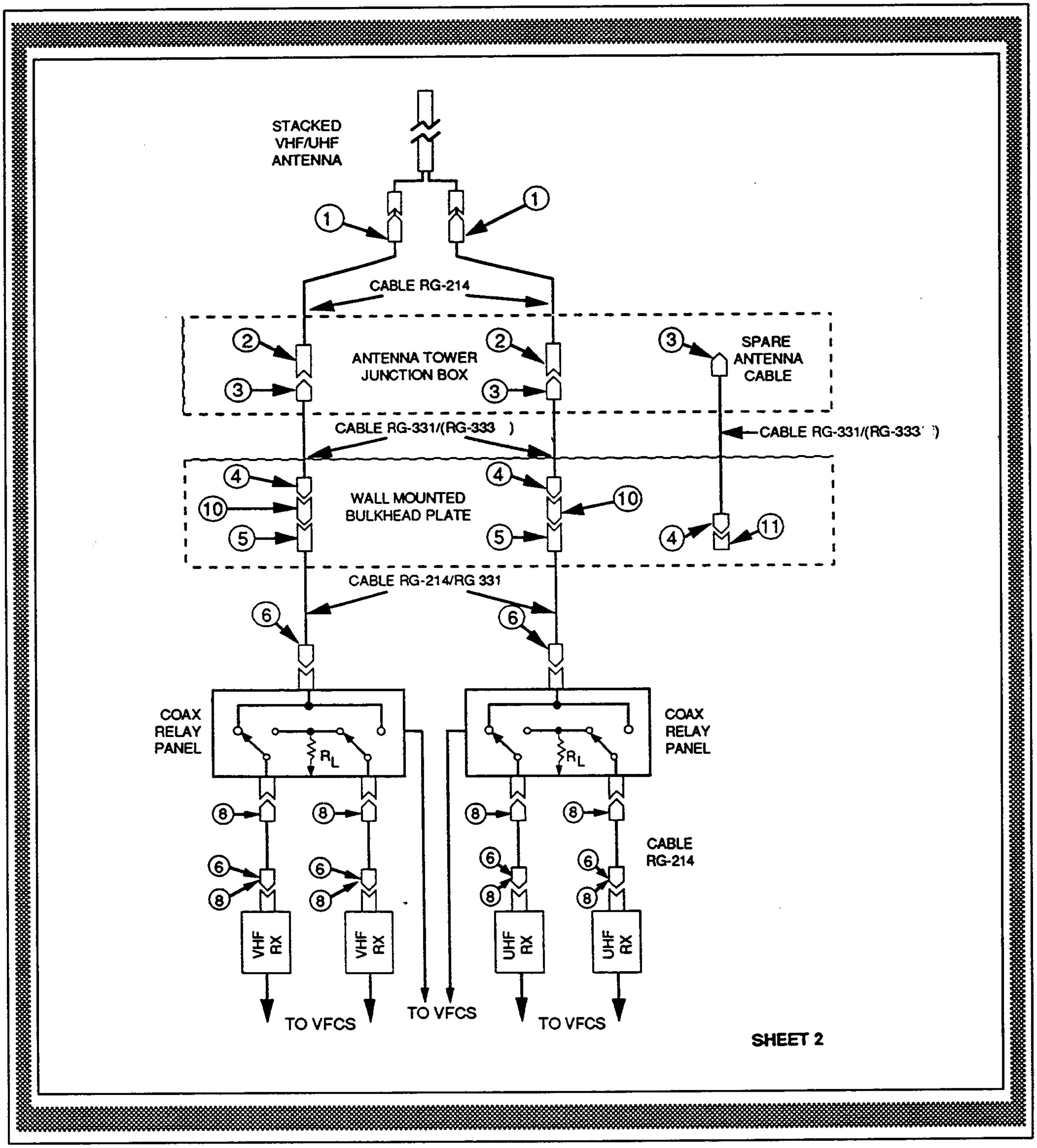


TABLE 6-1. ANTENNA SYSTEM MATERIALS LIST

ITEM NO.	CABLE TYPE	PART NUMBER	CONTACTS	SERIES	TYPE
1.	RG 214	UG-1185A/U	MALE	N	STR'T PLUG
2.	RG 214	UG-1185A/U	MALE	N	STR'T PLUG
3.	RG 331 RG 333	CWAVE 735001 CWAVE 735101	FEMALE FEMALE	N N	STR'T JACK
4.	RG 331 RG 333	CWAVE 735001 CWAVE 735101	FEMALE FEMALE	N N	STR'T JACK
5.	RG 214 RG 331	UG-1185A/U UG-147E/U	MALE MALE	N N	STR'T PLUG
6.	RG 214 RG 331	UG-1185A/U UG-147E/U	MALE MALE	N N	STR'T PLUG
7.	RG 223	UG-88C	MALE	BNC	STR'T PLUG
8.	RG 214 RG 214	UG-27	MALE MALE	N BNC	ANGLE PLUG
9.	RG 223	AMPHENOL P/N 82-5370	MALE	N	STR'T PLUG
10	-	Polyphase P/N IS-50	M/F	N	Impulse Suppressor
11.	Term'n 50 ohm	AMPHENOL P/N 45650-51	MALE	N	STR'T PLUG

Note: Connectors are weather proof, 50 ohm impedance.

a. **Transmitter Output Cable**. In combiner applications, install type RG-214 coaxial cable or equivalent from the transmitter RF output jack via the combiner cavities to the input of the designated RF coaxial line section panel located at the top of the transmitter equipment rack. In applications where coaxial transfer relay panels are used, RG-214 coaxial cable is installed from the transmitter output jack to the input jack of the coaxial relay. The output of the relay is connected to the RF line section with a length of RG-214 cable. In all cases the matching cable to connector type is used.

b. **Receiver Input Cable**. Install type RG-223 coaxial cable, or equivalent, from the receiver equipment RF input jack to the designated RF output of the active multicoupler or RF relay panel. Great importance shall be placed on this cable's length since cable attenuation is critical for this type cable. Cable length shall be as short as possible when equipment is placed in separate racks. In Transmit/Receive (T/R) relay applications special importance shall be placed on cable length. If the cable length is 25 feet or more, RG-214 shall be used with the applicable type connectors to connect to the multicouplers BNC input jacks. In cases where coaxial relay panels are supplied, type "N" connectors will be used with RG-214 type coaxial cable.

c. **Cavity Interconnect and Harness Cables**. The interconnect and harness cables are precut and fabricated for the specific combiner frequencies as shown in Figure 6-15, VHF Transmitter Combiner Cavity Cable Harness and in Figure 6-16, UHF Transmitter Combiner Cavity Cable Harness. Double-shielded RG-214 cable shall be used to minimize RF leakage that would allow signals to bypass the cavity filters. The cable lengths used for the interconnects and phasing cables are critical and have been optimized at the manufacturer for the specific frequencies to be combined and the tuning range of the cavities.

d. **Cavity Interconnect and Harness Cable Installation**. Ensure that the pre-fabricated factory-supplied interconnecting and harness cables packed with the cavities are connected as instructed for each transmitter frequency concerned. Double-shielded RG-214 coaxial cable and silver-plated brass connectors shall be used. Ensure that the cables do not have sharp bends or kinks and are supported with nylon cable ties to minimize any physical strain on the coaxial cable connectors.

FIGURE 6-15. VHF TRANSMITTER COMBINER CAVITY CABLE HARNESS

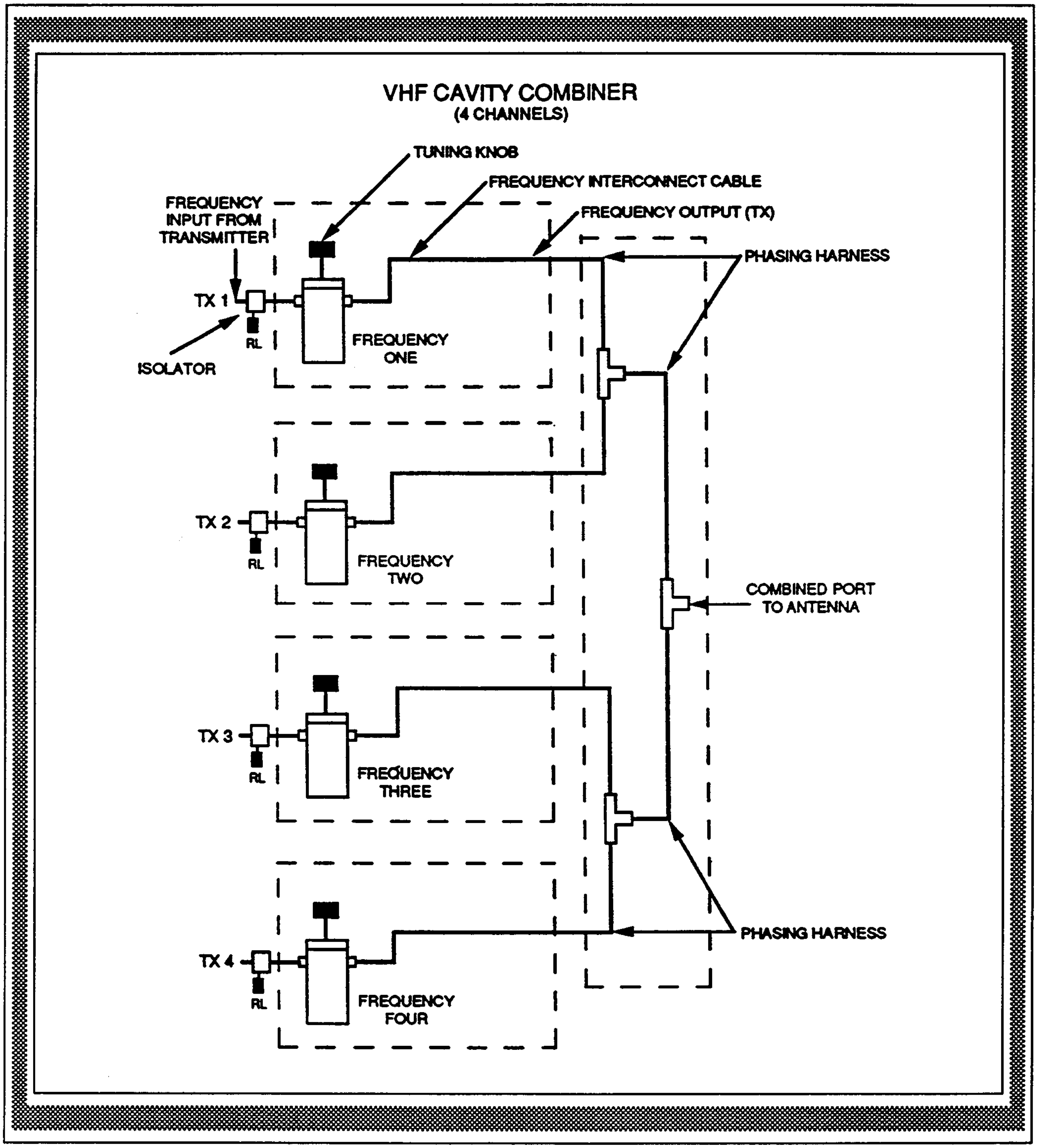
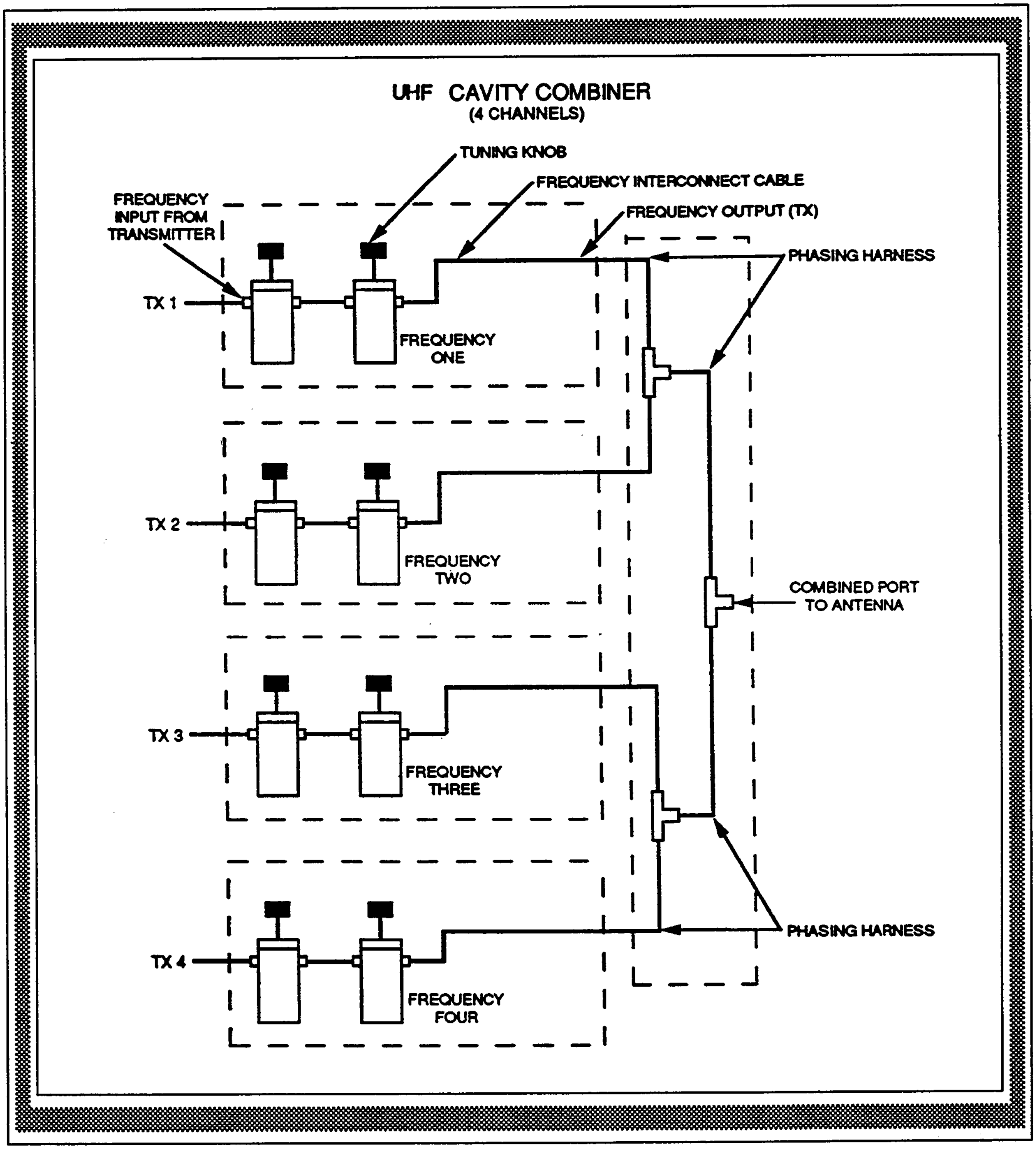


FIGURE 6-16. UHF TRANSMITTER COMBINER CAVITY CABLE HARNESS



e. <u>Transfer Relay Panel Cabling Configurations</u>. There are a number of RF cabling transfer configurations forms used with the RCF equipment to accommodate virtually all possible facility designs. Other variations are possible. The relay panels type "A" and "B" will be used in applications described in subparagraphs (1) to (5). In many applications the transmit/receive (T/R) relay inside the transmitter is used for receiver muting instead of these more specific application relay configurations.

(1) <u>Configuration 1</u>. The first form requires two antennas (one for transmitter equipment and one for receiver equipment) and three M/S type 1 relays. This configuration is shown in Figure 6-17, RF Cabling Transfer Relay Configuration 1.

(2) <u>Configuration 2</u>. The second form uses two antennas, one for main equipment and the second for standby equipment. Both T/R and M/S relays are used and may be either internal or external to the transmitter. This configuration requires the use of three separate relays; two T/R relays and one M/S relay. Both antennas are connected to T/R relays as shown in Figure 6-18, RF Cabling Transfer Relay Configuration 2.

(3) <u>Configuration 3</u>. The third form consists of up to four antennas: main transmit, main receive, standby transmit, and standby receive, or up to four ports to combiners and multicouplers for the same functions. This design feature is especially desirable when multicouplers and combiners are required. The number of antennas and feedlines required in applications without combiners or multicouplers make this configuration unacceptable. A single M/S relay is used in this configuration as shown in Figure 6-19, RF Cabling Transfer Relay Configuration 3.

(4) <u>Configuration 4</u>. The fourth form uses one antenna, with main/standby and either internal or external T/R relays, and is used when antenna space is extremely limited. The single antenna design requires one T/R relay and two M/S relays as shown in Figure 6-20, RF Cabling Transfer Relay Configuration 4.

(5) <u>LPA Transfer Relay Configuration</u>. RCF sites in some cases will require additional RF output power in order to increase their range of coverage. These sites will require installation of an LPA and a means of connecting the amplifier into a specific channel. Configuration 1 was adapted to provide for adding the LPA. Figure 6-21, LPA Transfer Relay Cabling Configuration (Proposed), shows the application of RF cabling transfer relay Configuration 1 with cabling. The relay panel type "B" was adapted and used for this application.

FIGURE 6-17. RF CABLING TRANSFER RELAY CONFIGURATION 1

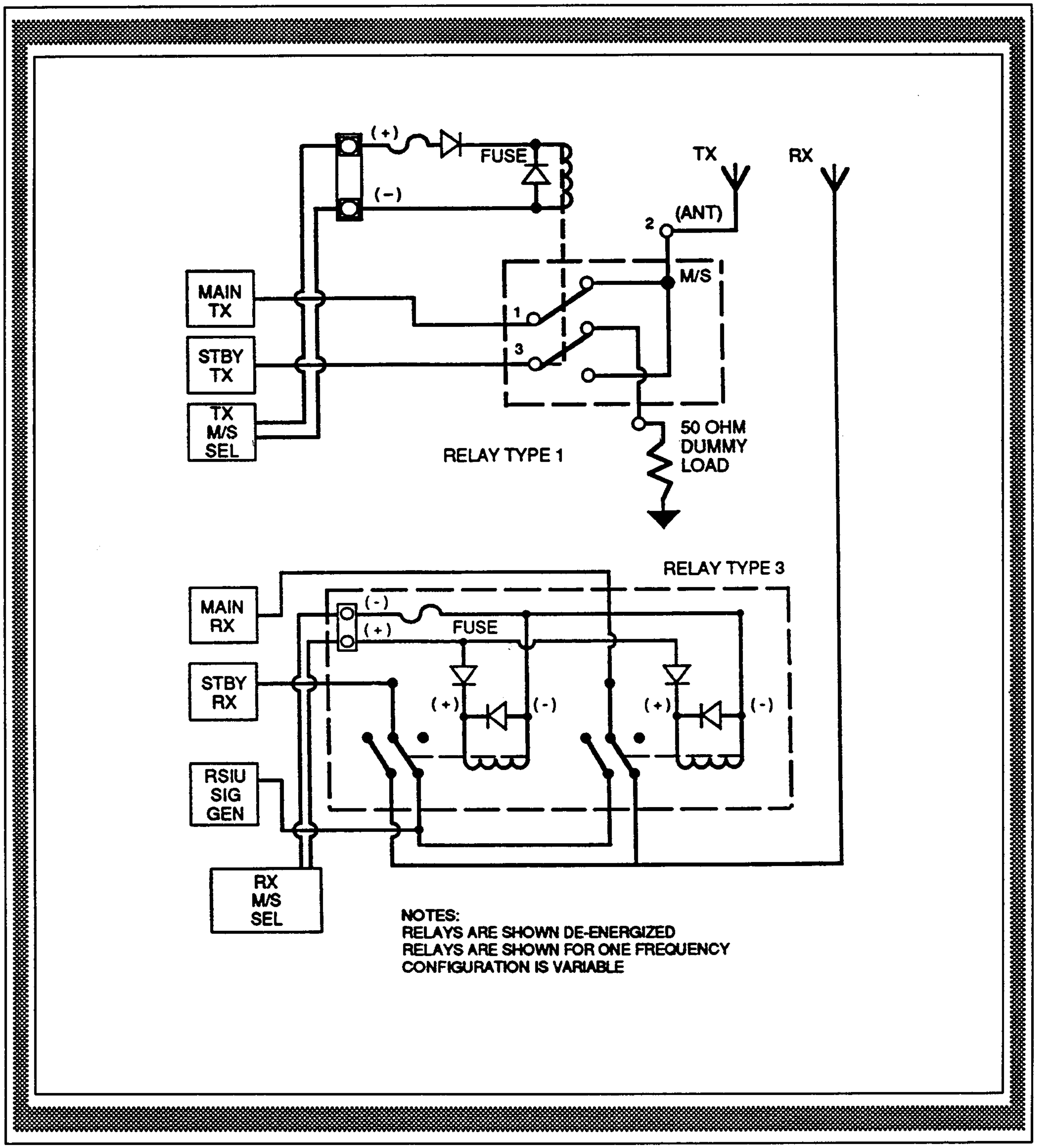


FIGURE 6-18. RF CABLING TRANSFER RELAY CONFIGURATION 2

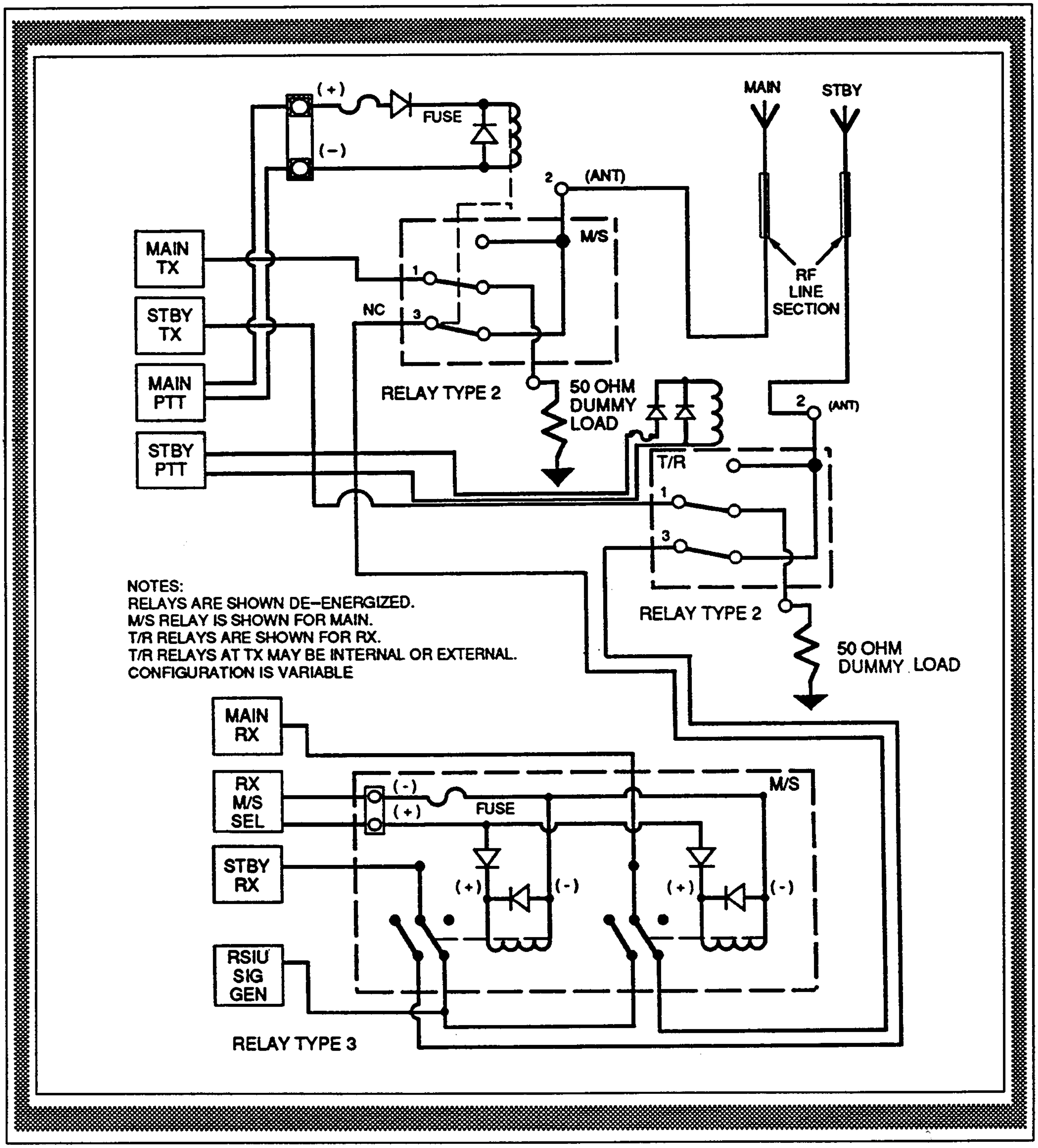


FIGURE 6-19. RF CABLING TRANSFER RELAY CONFIGURATION 3

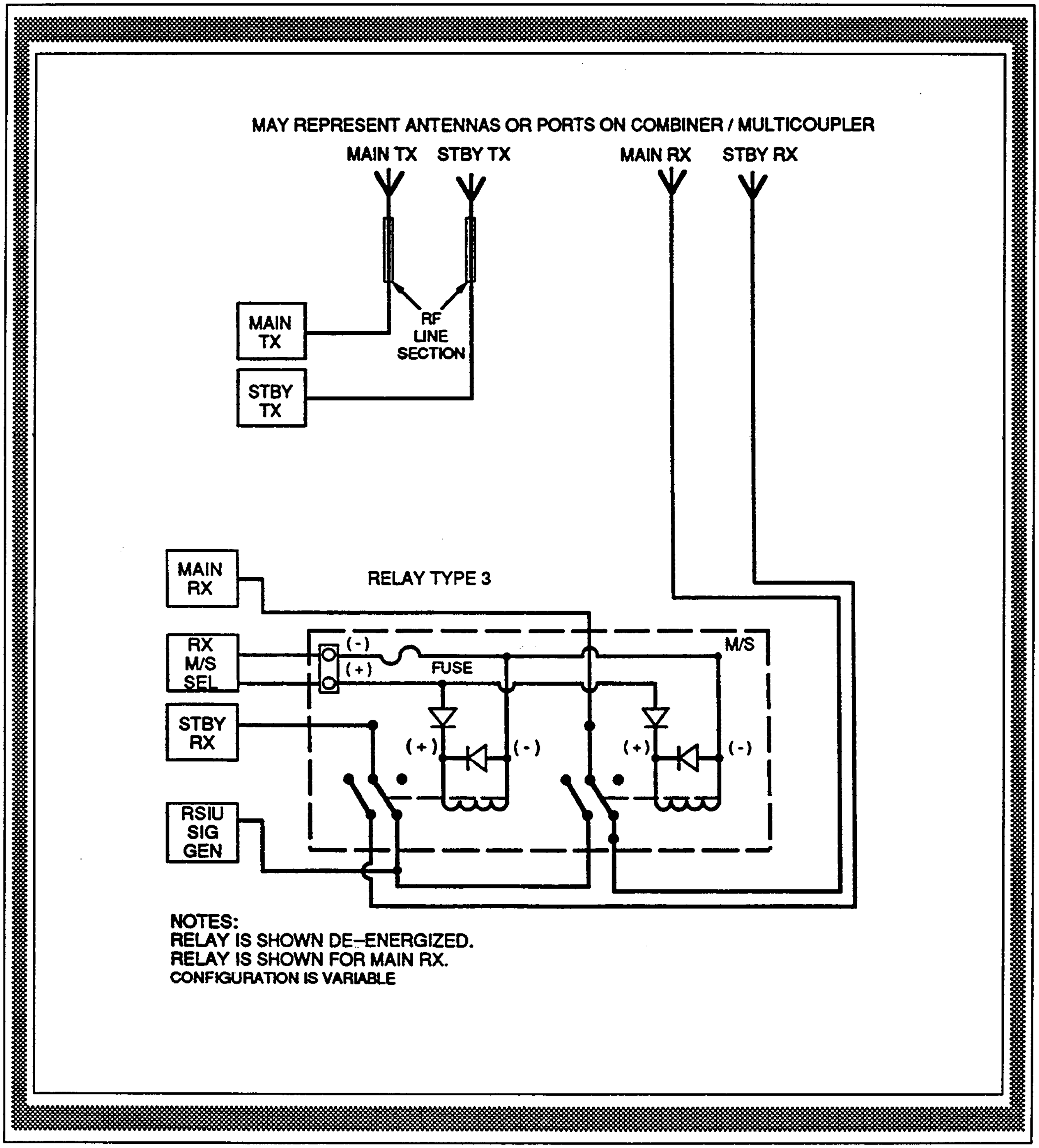


FIGURE 6-20. RF CABLING TRANSFER RELAY CONFIGURATION 4

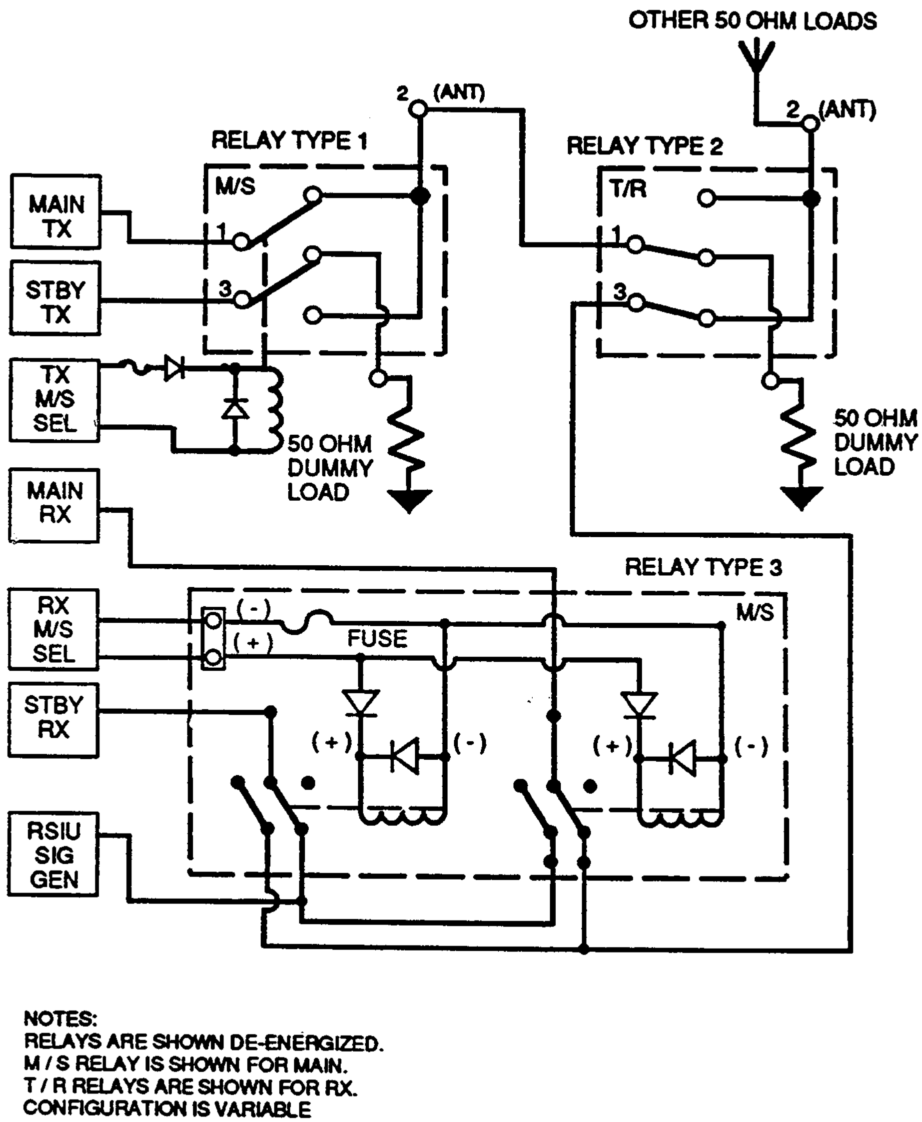
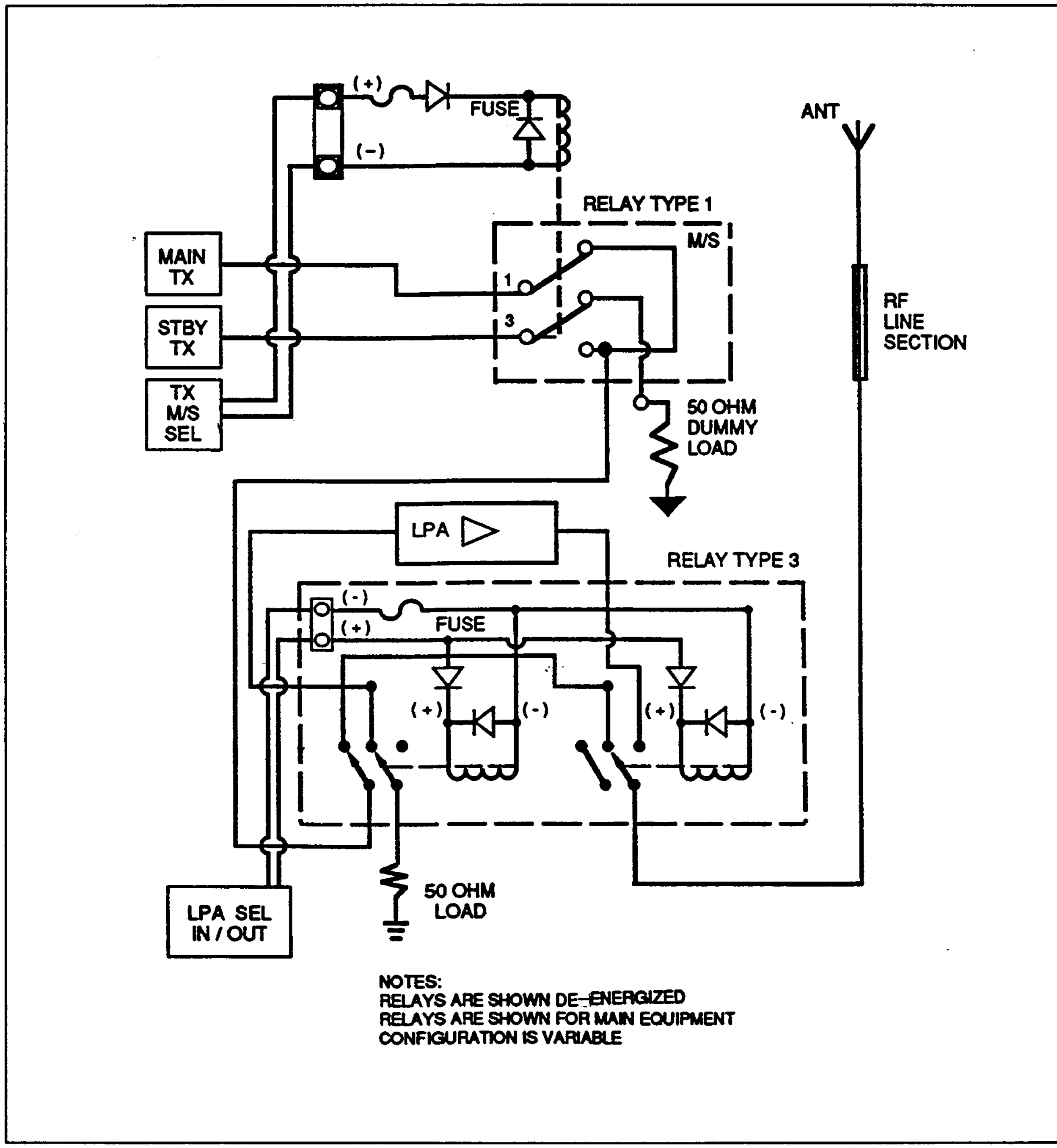


FIGURE 6-21. LPA TRANSFER RELAY CABLING CONFIGURATION (PROPOSED)



(6) **Coaxial Transfer Relay Panels**. Each of the RF relay cabling configurations is made up of typical transfer relay panels. Several relay types are used. Type 1 relay is contained in type "A" panel shown in Figure 6-22, Typical Coaxial Transfer Relay Panel Type A. A type 2 relay is the same except that the unpowered state is opposite type 1. Another relay type, Type 3, is contained in the type "B" panel shown in Figure 6-23, Typical Coaxial Transfer Relay Panel Type B. These panels are used in many sites to satisfy coaxial RF cable transfer requirements.

170.-172. **RESERVED**.

FIGURE 6-22. TYPICAL COAXIAL TRANSFER RELAY PANEL TYPE A

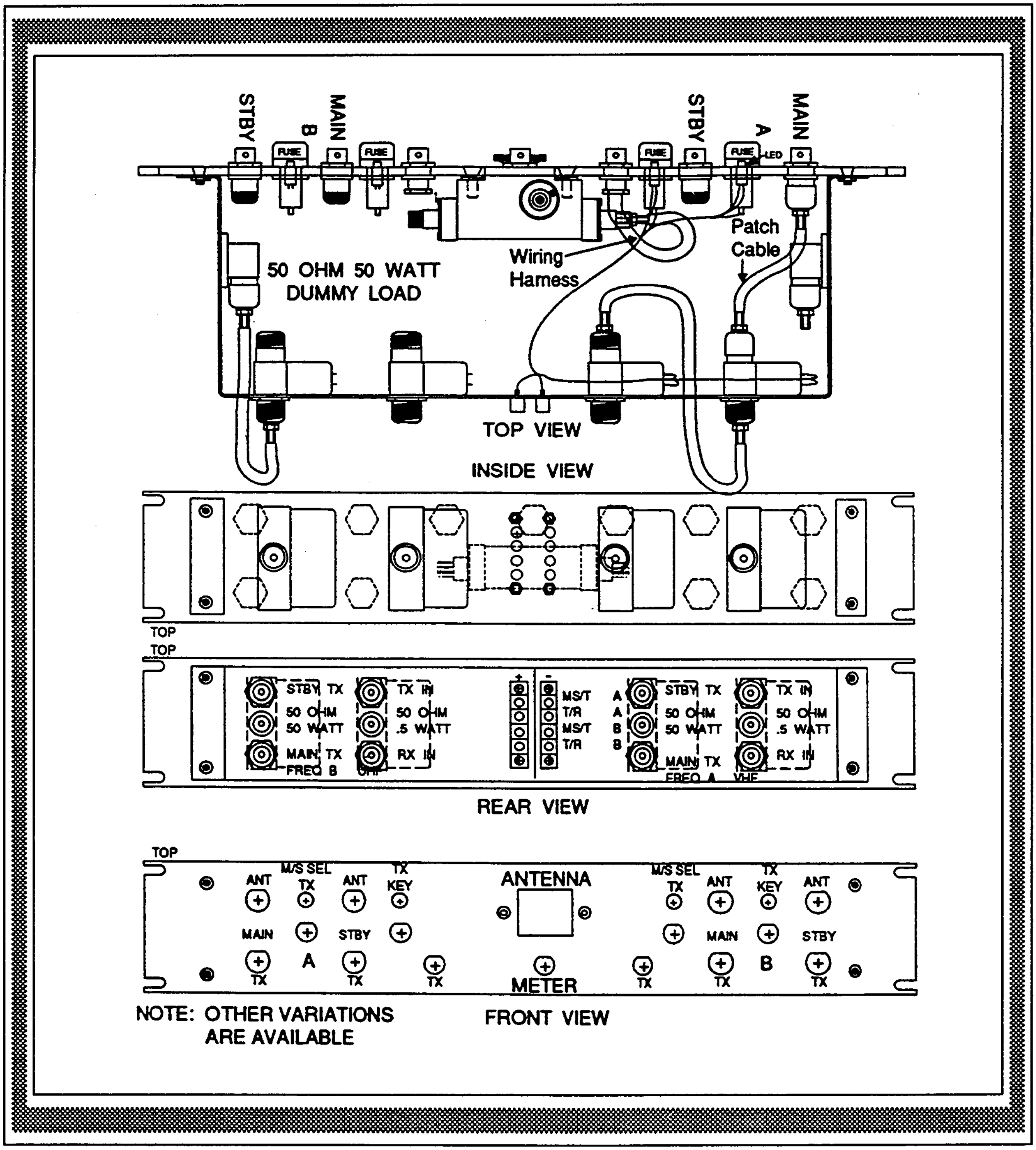
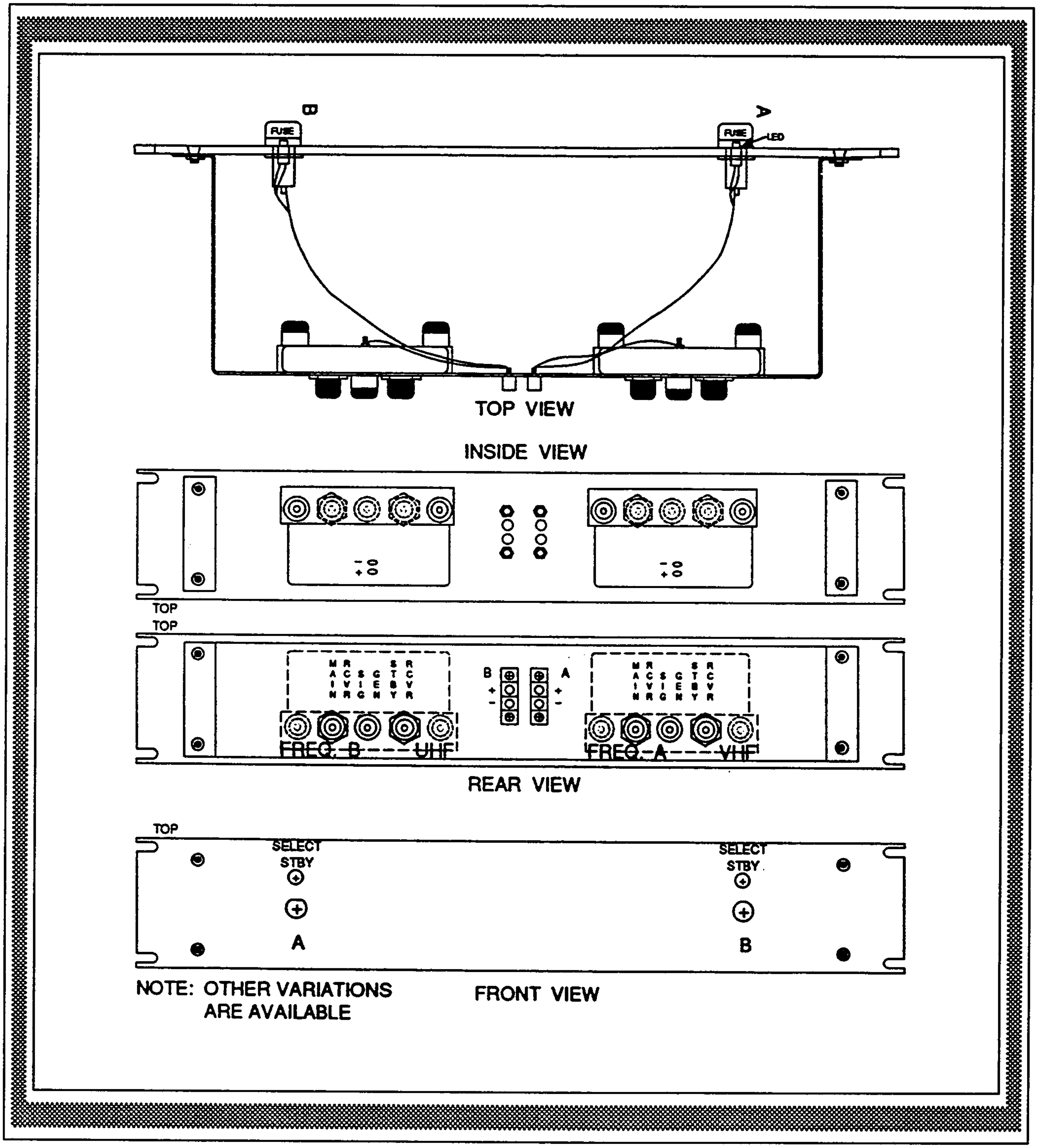


FIGURE 6-23. TYPICAL COAXIAL TRANSFER RELAY PANEL TYPE B



SECTION 4. ANTENNA RF CABLE PATCH PANEL, AND BULKHEAD PLATE INSTALLATION

173. **BUILDING ANTENNA RF CABLE PATCH PANEL**. The installation of an antenna cable patch panel provides a common point for manually interconnecting the RG-214, RG-331, and RG-333 coaxial cables. This common point for cable interconnection provides a means of switching antennas, coaxial cable transmission lines, and equipment for maintenance, emergency restoral, and troubleshooting operations. The building antenna RF cable patch panel installation typically consists of two patch panel cabinets. One cabinet provides coaxial cable transitions for transmitters from RG-214 to the RG-331 or RG-333 antenna transmission line. The second cabinet provides coaxial cable transitions for receivers from RG-214 to the RG-331 or RG-333 antenna transmission line. The independent transmit and receive patch panels provide improved isolation between the transmit and receive RF signal paths and improved routing for the cable runs between the building and the transmit and receive antenna towers. An RG-214 coaxial cable service loop shall be long enough to allow connection to any antenna feed cable as illustrated in Figure 6-24, Typical Wall Mounted Antenna Cable Patch Panel.

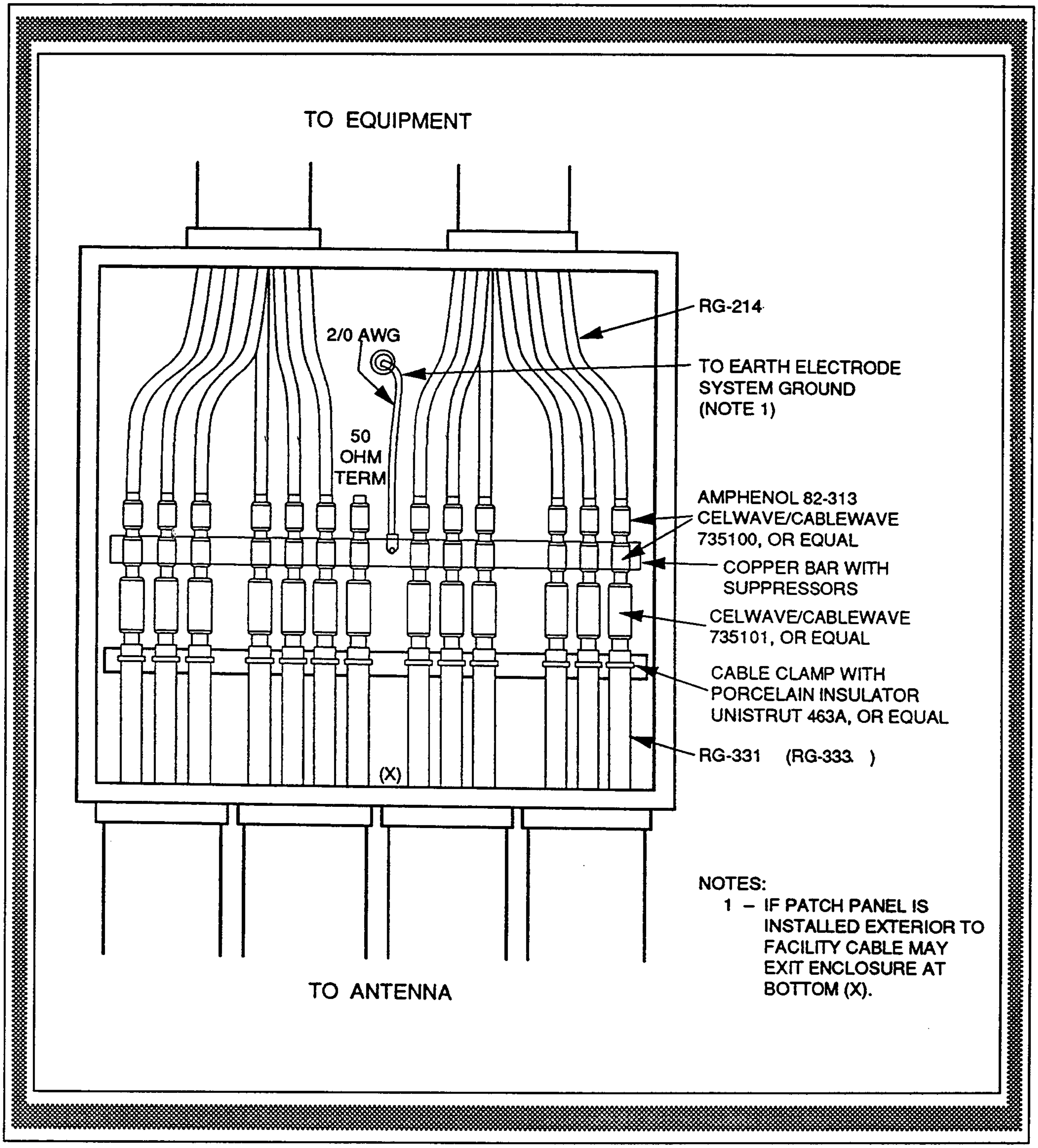
a. **Coaxial Cable Patch Panel Installation**. Patch panel installation is recommended in new facilities and is optional in existing facility upgrades. The size of the building antenna coaxial cable patch panel is dependent upon the number of antenna coaxial cables needed to support the facility. For example, two panels, 36-inch by 36-inch by 8-inch enclosures with twin full-access hinged doors are used to accommodate the 13 transmit and 13 receive cables required at a 24 frequency facility. This example includes two spare coaxial cables, one for transmit and one for receive.

(1) **Panel Location**. Panel enclosures should be located on an inside or outside wall near the point where the RG-331/RG-333 cables enter the building. The enclosures shall be installed no more than 4 feet above the floor level. The panel enclosures shall be attached to the wall with appropriate hardware.

(2) **Conduit Installation**. Sections of PVC conduit, or aluminum conduit sized to accommodate the existing conduit connectors, are installed between the floor cable entrance and the bottom of the patch panel. Use the manufacturer's recommended conduit fittings.

(3) **Restrictions**. The patch panel may be installed on an outside wall when space will not accommodate mounting it on the inside. A weather-tight cabinet shall be used for outside installation.

FIGURE 6-24. TYPICAL WALL MOUNTED ANTENNA CABLE PATCH PANEL



b. **Coaxial Cable Installation**.

(1) **Cable Installation**. Extend the RG-331 or RG-333 cable 2 feet into the patch panel. Cut the RG-331/RG-333 cable to a one foot length above the enclosure entrance conduit bushing. Install a type "N" female coaxial cable connector on the end of each RG-331/RG-333 cable (for RG-331 use Celwave 735001, or equal, and for RG-333 use Celwave 735101, or equal). Connector installation instructions that accompany each cable connector shall be used. Each cable shall be anchored to the rear of the enclosure panel with cable clamps that include a non-metallic bushing where the clamp wraps around the cable. These are shown in figure 6-24. As shown, all coaxial cables shall be common to the facility earth electrode ground system. A copper bar shall connect each cable connector together with others. Alternate methods may be used if site conditions require other solutions. Install the RG-214 cables from the transmitter combiner outputs and from the receiver multicoupler's input ports through the top of the patch panel enclosure as shown in figure 6-24.

(2) **Wireways**. Metal cable trays in the building shall be used to support the RG-214 coaxial cables between the RCF communications racks and the coaxial cable patch panel enclosure. Ensure that a grounded metallic barrier exists between the coaxial cables and any audio, control, or power cables within the cable trays.

(3) **Patch Panel Cable Junction**. RG-214 cable shall extend through the top of the patch panel enclosure and approximately 3 feet into the open space. Sufficient cable slack shall be made available in the RG-214 cable to allow connection with any RG-333 cable fitting. Conduit cable protection bushings shall be installed at the enclosure's top entrance. Prepare the RG-214 cables and install a type "N" male coaxial cable connector on each cable. For RG-214, use a UG-1185 type connector or its equivalent. Cable connector installation instructions that accompany the connectors shall be used. Cables shall be supported within the patch panel enclosure with cable ties and/or cable clamps to ensure that the weight of the cables is evenly distributed.

(4) **Grounding**. Install a No. 2/0 AWG insulated cable from the antenna patch panel cable grounding bar or building bulkhead plate to the facility earth electrode ground system. Grounding shall be in accordance with FAA-STD-019b, Lightning Protection, Grounding, Bonding and Shielding Requirements for Facilities.

174. **ANTENNA RF CABLE BULKHEAD PLATE**. Remote communications facilities that have relatively short coaxial cable transmission line runs between the building and the antenna tower or pole will use a coaxial cable bulkhead wall plate. The building coaxial cable feedthrough provides a means of feeding coaxial cables into the building. There are two general types of coaxial cable feedthrough bulkheads.

a. **Coaxial Cable Feedthrough Installation**. The typical coaxial cable feedthrough bulkhead plate is a copper plate installed on the building wall to support coaxial cable bulkhead adapters (type "N," jack-to-jack feedthrough, Amphenol No. 90950, or equal) as shown in Figure 6-25, Antenna Coaxial Cable Bulkhead Plate. Type "N" male coaxial cable connectors shall be installed on interior RG-214 coaxial cable. Watertight type "N" male coaxial cable connectors shall be installed on RG-331/RG-333 cable. The type "N" bulkhead adapter shall be installed through the bulkhead. Ensure cable slack is available for future modifications and changes.

b. **Alternate Coaxial Cable Feedthrough Installation**. An alternate type of cable bulkhead installation provides a water-tight building wall feedthrough as shown in Figure 6-26, Alternate Wall Bulkhead Feedthrough. The cable is passed through the wall and connected directly to the equipment in the racks or you can use the method as shown in figure 4-31a. The method shown will provide an interior connection point for an RF cable surge suppressor installation and a cable junction point.

(1) **Bulkhead Plate Grounding**. In both applications install a No. 2/0 AWG cable from the copper bulkhead plate to the earth electrode system in accordance with FAA-STD-019b. See figure 6-25 for an illustration of bulkhead plate grounding.

175.-177. **RESERVED**.

FIGURE 6-25. ANTENNA COAXIAL CABLE BULKHEAD PLATE

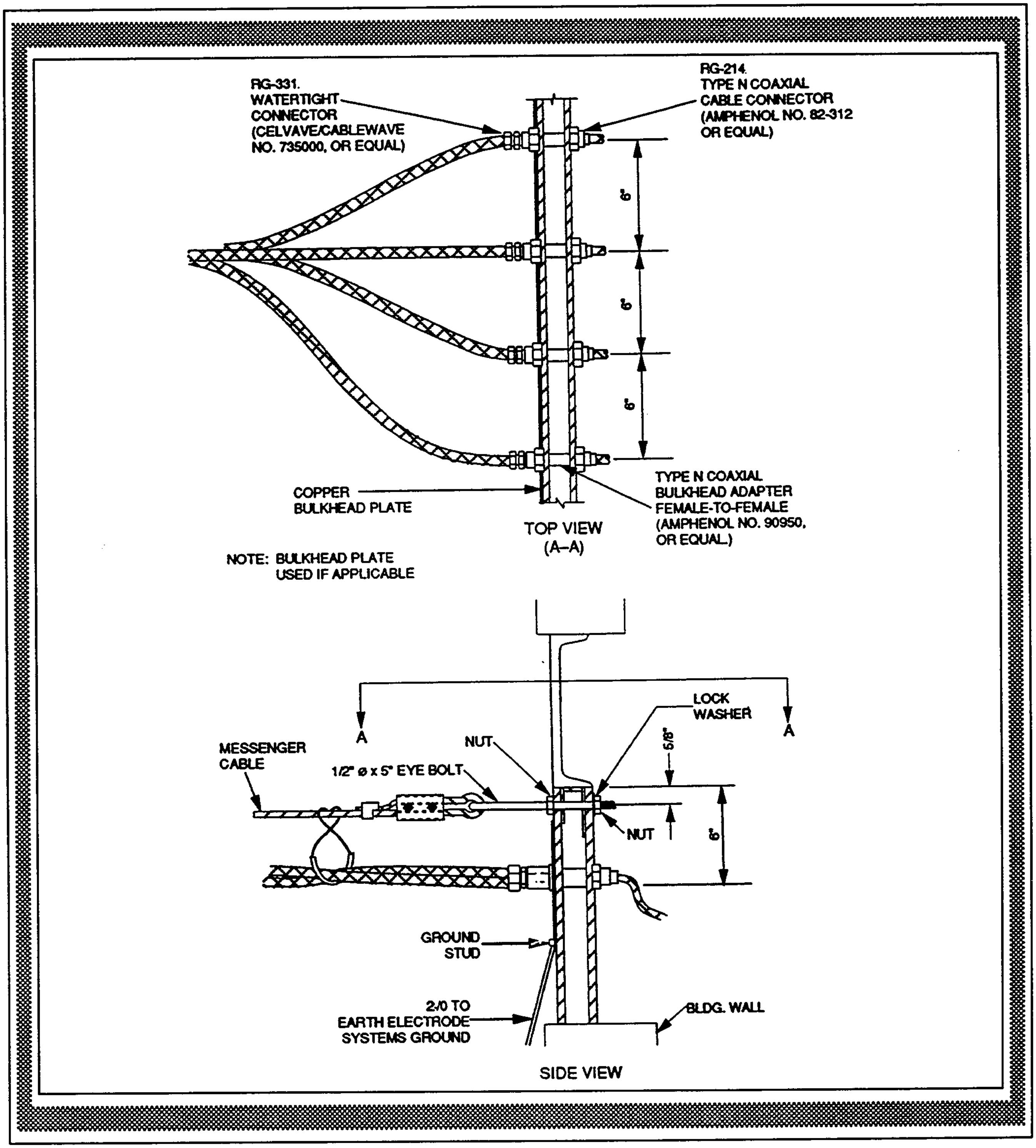
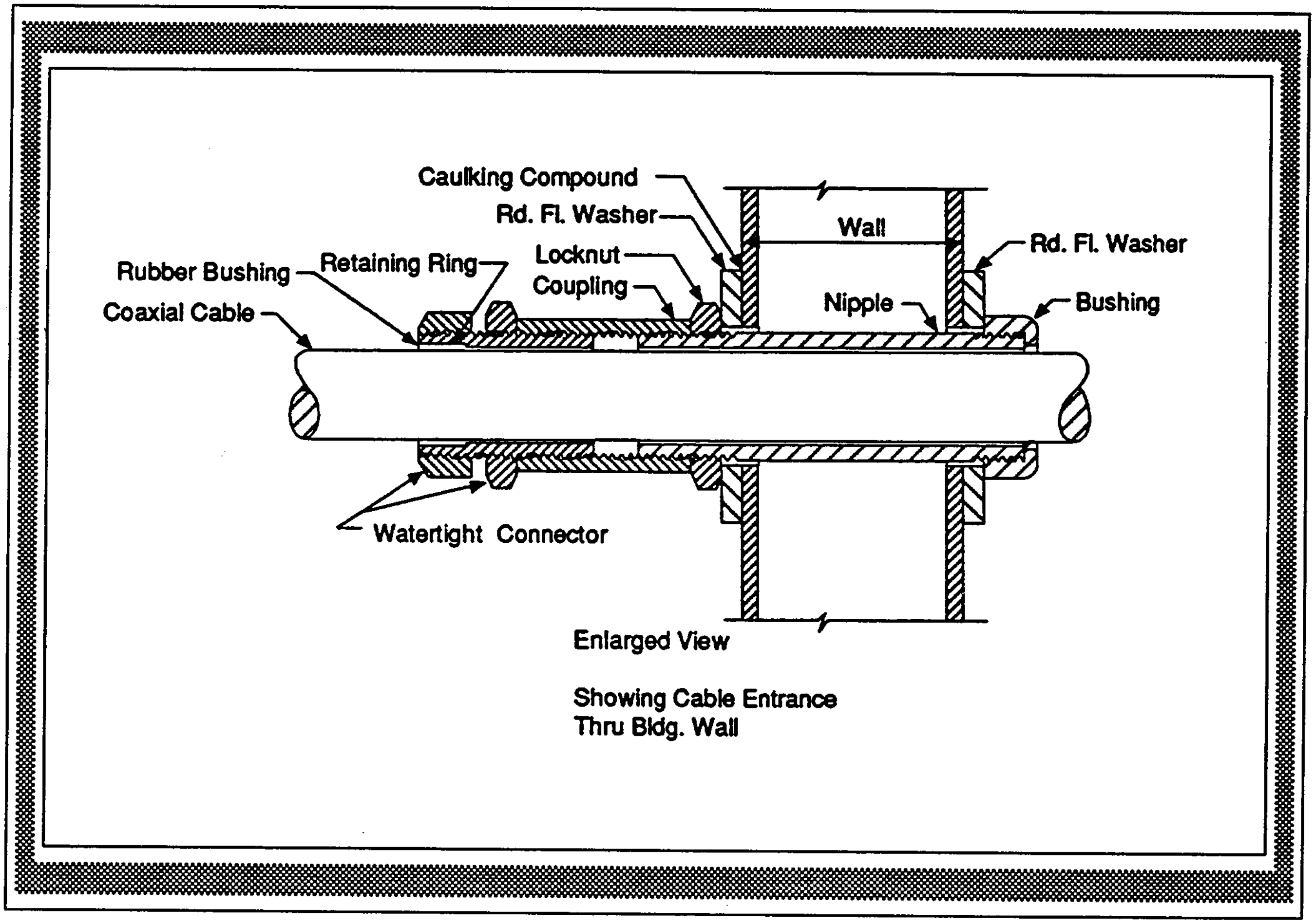


FIGURE 6-26. ALTERNATE WALL BULKHEAD FEEDTHROUGH



SECTION 5. ANTENNA SYSTEM INSTALLATION

178. **DESIGN GUIDELINES AND REQUIREMENTS**. The following guidelines and requirements shall be used in the design of the RCF antenna systems to minimize receiver desensitization and RF intermodulation; reduce antenna pattern distortion; provide lightning protection; and provide transmission line and antenna backup capabilities.

a. **Antenna Coaxial Cable**. Low loss double-shielded and/or solid sheath coaxial cable transmission lines shall be used for antenna coaxial cables. At least one spare coaxial cable transmission line shall be installed for each antenna tower. Spare cables shall be terminated on the patch panel end by a 50 ohm load.

b. **Antenna Junction Box**. One antenna cable junction box shall be installed for each antenna tower or pole platform. This water-tight enclosure enables coaxial cable type transition and spare cable substitution.

c. **Antenna Spacing**. Recommended spacing between transmit and receive antenna towers is 120 feet, which provides a free space path loss of approximately 46 dB at VHF and 54 dB at UHF frequencies. Path losses minimize interference in receivers by attenuating transmitted sideband energy. Some existing towers are spaced 80 feet apart. The additional 3.5 dB isolation gained by 120 feet separation must be justified if spacing changes are to be made. Although T/R adjacent operation is not recommended, minimum spacing of 8 feet is recommended between adjacent transmit, receive, or T/R antennas. Spacing transmit antennas at least 8 feet apart reduces generation of intermodulation products within adjacent transmitters. Antennas in groups, like those mounted on ATCT and AFSS building roofs, shall be separated as much as possible within the available mounting space. Spacing antennas less than the 8 feet minimum may require additional RF filtering devices such as notch or bandpass filters to minimize interference.

d. **Antenna Configuration**. Both single and stacked VHF and UHF antennas are used in antenna system configurations. Stacked antennas reduce the number of support towers required, but stacking shall be consistent with good design and site operation requirements. Space between antennas in a transmit or receive group of antennas shall be 8 feet minimum. Transmit antennas shall be mounted on separate transmit towers when adjacent frequencies are separated by less than 1 MHz VHF or 2 MHz UHF and combiner cavities or other filtering will not prevent interference. If T/R antennas are required, they may be collocated on transmit or receive towers only if at least 8 feet antenna spacing and 1 MHz adjacent frequency separation, VHF or UHF, are maintained. If intermodulation or receiver desensitization occurs, more filtering devices must be added or the antenna must be relocated to eliminate the interference.

e. **Air Terminals and Other Conductive Elements**. Air terminals and other conductive elements shall not be located within 8 feet of any antenna element. All metallic sharp points within 60 inches of the air terminal shall be cut back or rounded to prevent corona discharge. See chapter 4, figure 4-14, for a location illustration.

f. **Grounding**. A grounding conductor shall be installed from the antenna cable junction box grounding bar to the RCF earth electrode system via the tower down conductor. Some antenna manufacturers provide a ground stud at the base of their antennas. This stud shall be connected to a grounding down conductor. Grounding shall be installed in accordance with FAA-STD-019b. See chapter 4, figure 4-20, for a grounding illustration.

179. **MAINTENANCE CONSIDERATIONS**. Mounting arrangement for the antennas and all associated equipment shall, whenever possible, provide a practical and safe means for one person, working alone, to switch coaxial cable antenna lines and to lower or dismount each antenna for maintenance service or replacement.

180. **INTERFERENCE REDUCTION**. Utilizing the guidelines described in paragraph 178 for determining the antenna configurations will reduce antenna pattern distortion, receiver desensitization, and transmitter intermodulation. The following are more complete explanations of these sources of interference.

a. **Antenna Pattern Distortion**. In most applications, the desired antenna radiation pattern has circular symmetry moving outward from the antenna. Any conducting elements in the near field (8 feet) of the antenna may distort the pattern to some degree. Antenna pattern distortion can be reduced by increasing the space between antennas, air terminals, and other conductive elements, and by positioning the antenna configuration so that a metallic mounting structure causes minimum pattern distortion.

(1) **Antenna Configuration Exceptions**. There may be exceptions to why the antenna configuration is not satisfactory. The exceptions may depend upon the degree of antenna pattern distortion, the degree of receiver desensitization, the amount of transmitter noise and amount of intermodulation that exists at a given facility. An alternate antenna configuration will be considered, or filters and other interference control devices will be added at a facility to provide required antenna system performance.

b. **Receiver Desensitization and Transmitter Noise**. Receiver desensitization may occur whenever a transmit antenna located less than 120 feet from a receive antenna transmits on a frequency 500 kHz VHF or 1 MHz UHF from a receiver center frequency. T/R antennas must maintain a frequency separation of 1 MHz VHF or UHF in any case. Transmitted signals can include transmitter noise with interfering intermodulation products. Signal degrading effects of receiver desensitization and transmitter noise are minimized by maintaining adequate physical spacing and frequency separation between antennas and, when necessary, by the use of supplemental devices such as combiners and cavity or crystal filters.

c. **Transmitter Intermodulation**. Transmitter intermodulation occurs when two or more signals of different frequencies interact to generate interfering new frequencies known as intermodulation products. Transmitter intermodulation is more prevalent when large numbers of transmitting antennas are grouped together on towers. Transmit or T/R antennas involved in transmitter intermodulation interference should be moved or extra filtering may be required to reduce or eliminate the interference.

(1) **Antenna Counterpoise Conductance**. Transmit antennas mounted on buildings containing non-uniform metal surface junctions, such as an AFSS building roof, may cause intermodulation interference. Seals where metal roof material joins other metal material near the transmit antenna can cause nonlinear conductance when the junction is oxidized or has a poor metal-to-metal bond. This condition will generate noise and intermodulation interference. When the problem is encountered, measures shall be taken to prevent interference by cleaning oxidized junction surfaces or bonding metal straps across suspect junctions.

181. **INTERFERENCE RESOLUTION**. After the interference reduction methods described in paragraph 180 have been tried and found for one reason or other not to be suitable, bandpass and band rejection devices shall be considered. These devices can cause signal attenuation to the receiver and lower antenna output power for the transmitter. If these factors are considered, losses will be minimized.

a. **Interference Reduction Devices**. Cavity bandpass filter devices will aid interference rejection for both the transmitter and the receiver. The value of this device is limited by the interference amplitude since out-of-band rejection may not be sufficient to attenuate the offending signal or noise. Receiver interference will be attenuated by the use of a crystal bandpass filter at the receiver. This device is small enough to be placed in the coaxial cable path. It will attenuate out-of-band (outside of the 50 kHz bandwidth) interference by 40 decibel relative to 1 microvolt (dBm) or more. If a specific frequency is at fault, a notch or narrow single frequency crystal filter will be necessary.

b. **Receiver Interference**. On the transmitter side, interference creating sideband noise or sideband harmonic energy products will desensitize any "near-in-frequency" receivers. Cavity bandpass filters or cavity band reject filters will be used to minimize radiation of the interfering noise or harmonic. Close attention is required in selecting cavity filters since in-band attenuation may be significantly large and out-of-band attenuation expected will occur further away from the frequency of interest than in similar crystal filter devices.

c. **Combination of Devices**. If an added filter does not reduce interference sufficiently, a combination of remedial devices must be used. Be aware that added devices can attenuate transmit and receive signals enough to impact a service volume. A ferrite isolator may be used in an interfering transmitter; however, an isolator can produce undesirable harmonics and may require additional narrowband filtering. Isolators minimize transmit sideband energy produced when energy from other transmitters or the transmitter's reflected energy enters the transmitter and mixes with the original frequency. Devices are illustrated in Figure 6-27, Typical Interference Reduction Devices.

182. **FREQUENCY INTERMODULATION ANALYSIS**. Intermodulation analysis shall be coordinated with the regional and/or the FAA headquarters frequency management office. This office will coordinate computer analysis of potential harmonic, image, and intermodulation interference. An analysis shall be made of the assigned frequencies to determine if intermodulation products will cause interference problems.

183. **STAND-ALONE RCF ANTENNA CONFIGURATION**. An antenna configuration for a stand-alone combined transmitter and receiver RCF is shown in Figure 6-28, Twelve Frequency Antenna Configuration. The site consists of two towers with the building between the towers. Tower separation of 120 feet and the use of 10 watt transmitters, combined with a minimum frequency separation of 500 kHz VHF and 1 MHz UHF, minimizes receiver desensitization. T/R antennas require a minimum of 1 MHz frequency separation for VHF and UHF.

a. **Antenna Complement**. The combined transmitter/receiver site may employ six VHF/UHF, UHF/UHF, or VHF/VHF transmit and six VHF/UHF, VHF/VHF, or UHF/UHF receive stacked collinear antennas.

b. **Pattern Distortion**. Antenna pattern distortion for tower-mounted stacked collinear arrays may occur which can cause a variance in the manufacturer's predicted antenna pattern gain characteristics by as much as 4 dB. Pattern distortion and its effect on air traffic radio coverage shall be considered when selecting antenna mounting configurations.

FIGURE 6-27. TYPICAL INTERFERENCE REDUCTION DEVICES

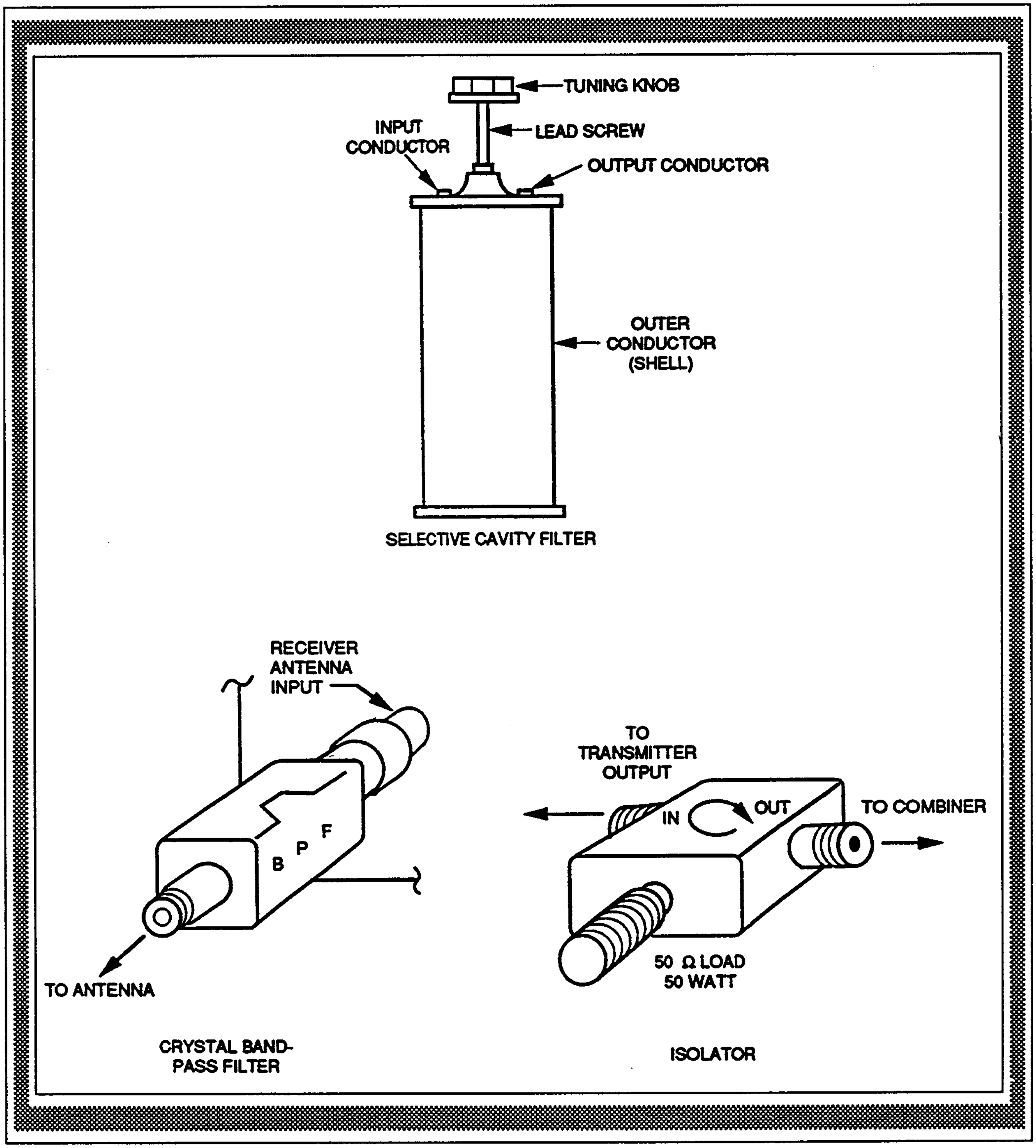


FIGURE 6-28. TWELVE FREQUENCY ANTENNA CONFIGURATION

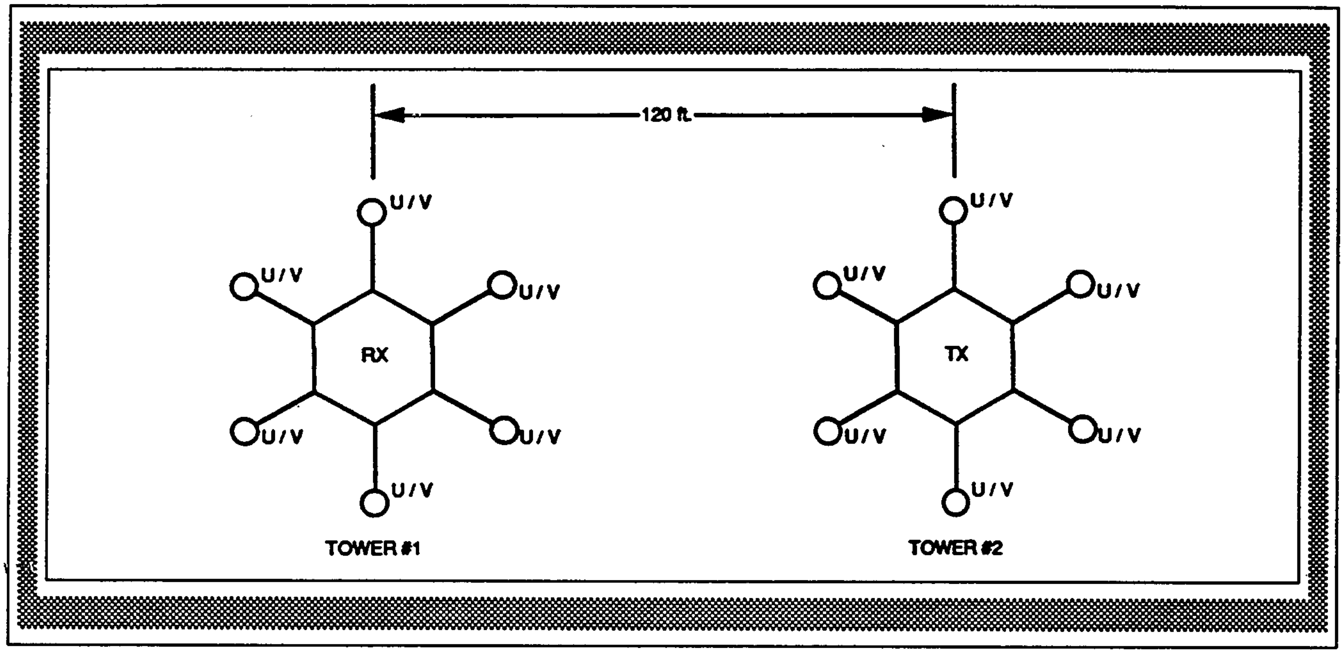
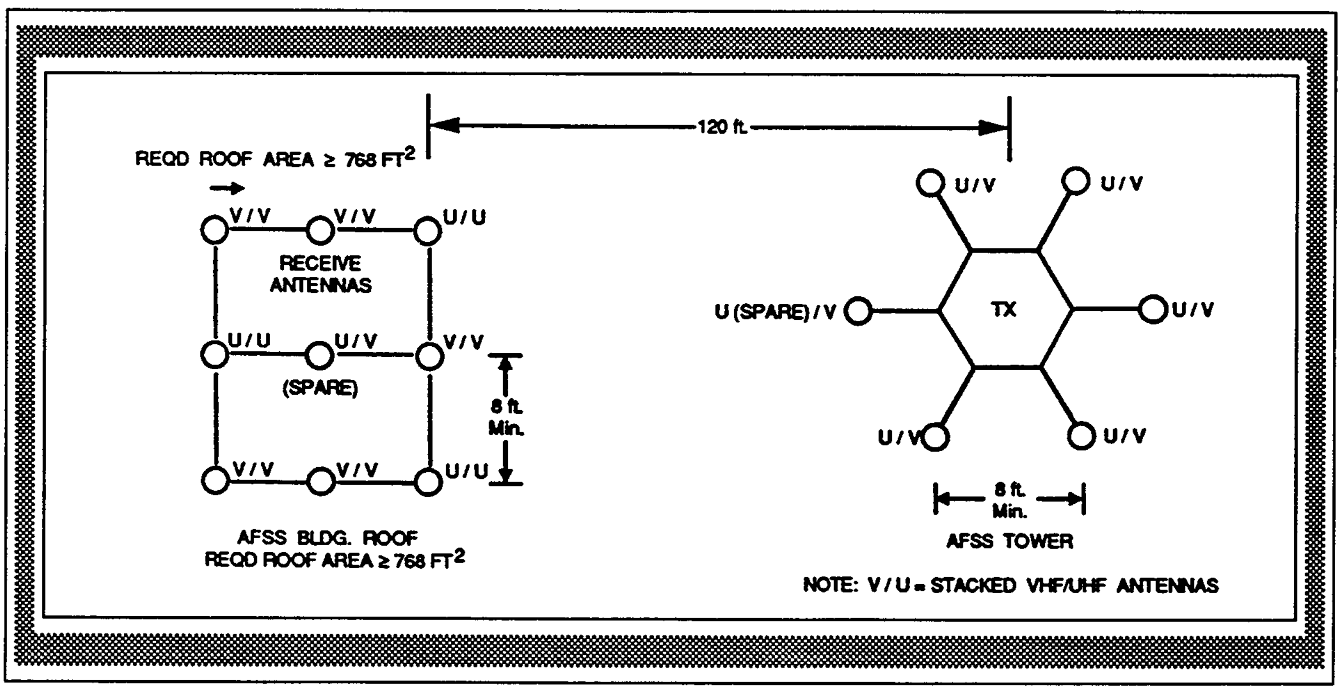


FIGURE 6-29. ANTENNA CONFIGURATION FOR RCF COLLOCATED AT AFSS



184. **COLLOCATED RCF AT AFSS FACILITY**. A basic antenna configuration for a collocated RCF at an AFSS facility utilizing stacked collinear antennas is shown in Figure 6-29, Antenna Configuration for RCF Collocated at AFSS.

a. **Receive Antenna Complement**. The typical facility uses five VHF/VHF receiver stacked antennas, three UHF/UHF receiver stacked antennas, and one UHF/VHF receiver stacked spare antenna system located on the roof of the AFSS building.

b. **Transmit Antenna Complement**. The typical facility uses up to six VHF/UHF stacked collinear antennas mounted on a single tower. The transmit tower shall be located a minimum of 120 feet from the receive antenna tower.

c. **Pattern Distortion**. Pattern distortion may occur if the facility roof is made of conducting material and is not properly grounded. Pattern distortion for tower-mounted stacked collinear antennas may vary between 1 and 4 dB.

185. **RCF COLLOCATED AT VORTAC**. The typical VOR with TACAN (VORTAC) facility utilizes antenna poles spaced 60 feet on a radius from the center of the VOR antenna array as shown in Figure 6-30, Typical RCF Collocated with VORTAC. The transmit and receive antenna poles shall be separated a minimum of 120 feet.

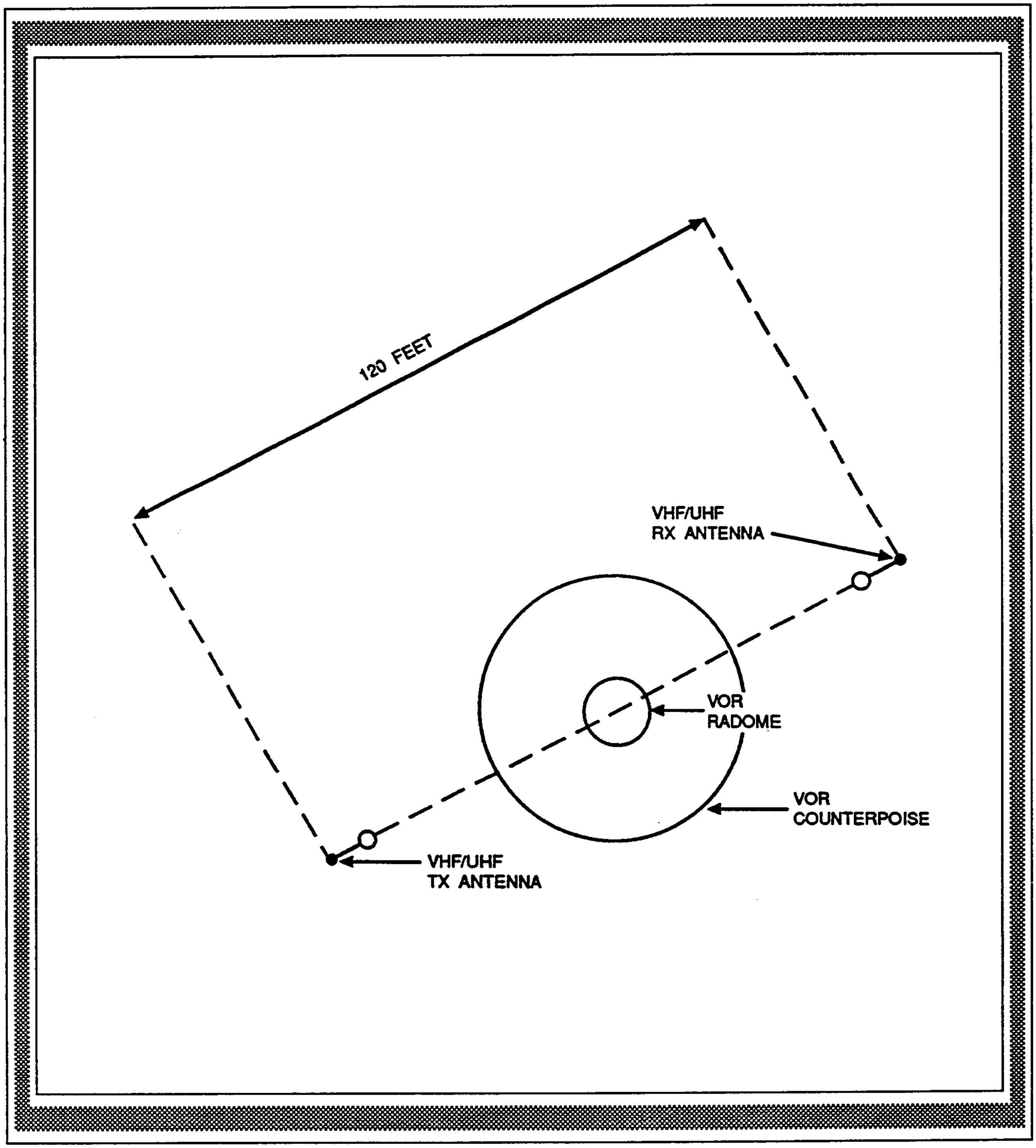
a. **RCF/VORTAC Let-Down Pole Antenna Complement**. The RCF collocated at a VORTAC host facility that utilizes let-down poles has two VHF/UHF stacked collinear elements at the lower cross-arm and two VHF/UHF stacked collinear elements at the upper cross arm. The cross arms shall be installed on a radial to the VORTAC. Refer to the figure 6-38 for an illustration.

b. **Pattern Distortion**. Horizontal spacing shall be no less than 8 feet between the VHF/UHF stacked collinear antenna elements. Antenna pattern distortion for the let-down poles may vary between 1 and 4 dB.

186. **RCF COLLOCATED AT AN AIR ROUTE SURVEILLANCE RADAR**. The RCF communications antennas collocated at an ARSR facility can be mounted on the ARSR antenna tower. Each RCF site shall be evaluated separately, and antenna locations selected in accordance with local site conditions. This application is technically feasible but, is not encouraged due to numerous potential problems.

187. **RCF FOR AN AIRPORT TRAFFIC CONTROL TOWER**. Recommended antenna configurations for ATCT facilities vary according to facility characteristics. It is recommended, but not required, that the RCF site be located a minimum of 1,500 feet from the control tower.

FIGURE 6-30. TYPICAL RCF COLLOCATED WITH VORTAC



a. **Antenna Configuration with Remote RCF**. An ATCT may utilize a remote RCF site having stacked collinear antennas on both transmit and receive antenna towers. The RCF equipment building should be located mid-distance between the two towers. In this configuration, the potential for intermodulation product interference is entirely within the RCF site. Transmit and receive antenna tower separation of not less than 120 feet and the use of 10 watt transmitters minimize receiver desensitization from transmitter sideband noise. A 500 kHz VHF and 1 MHz UHF minimum frequency separation between channels shall be maintained for separate transmit and receive antennas. T/R antennas require 1 MHz minimum frequency separation VHF or UHF.

b. **Antenna Configuration with Local RCF**. The ATCT with a local RCF shall separate the receiver antennas 120 feet from the transmitter antennas by installation of a remotely located transmit antenna tower.

c. **Antenna Pattern Distortion**. Maximum pattern distortion for the lower antenna elements of a two-stack collinear antenna is generally higher than for single antennas. Analysis indicates that total pattern distortion at any lower VHF antenna position is less than 3.4 dB and for any upper VHF antenna position, less than 2.0 dB. Total pattern distortion at any lower UHF antenna position is less than 2.2 dB and any upper UHF antenna position, less than 1.4 dB. UHF pattern distortion values are for the UHF stack opposite the empty position (worst case) on an antenna platform. The lower UHF element adjacent to the empty position exhibits 1.0 dB pattern distortion, and the upper UHF element in the same stack exhibits 0.6 dB pattern distortion.

188. **MATERIAL AND EQUIPMENT**. The typical RCF antenna site configuration shall consist of the following general materials and equipment. A more detailed configuration and materials list is shown in figure 6-13 and table 6-1.

a. **Coaxial Cable**. Low loss double-shielded or solid sheath coaxial cable shall be used in exterior cable installations at the RCF facility. Three types of MIL-STD type RF coaxial cables are available for use in new and upgraded installations: RG-214, RG-331, and RG-333.

b. **Coaxial Cable Junction Box**. The coaxial cable junction box shall be installed on the railing of the antenna tower or pole platform. The junction will allow for cable transfers between active and spares.

c. **Antenna Support Structures**. The typical support structure for the RCF antenna system is a metal tower or a non-metallic antenna pole and platform. The type of structure used will depend on the site requirements.

189. **ANTENNA SYSTEM INSTALLATION SUMMARY**. Following is a description of the RCF antenna system installation procedure.

a. **Site Survey**. An installation site survey shall be performed to verify the material and tool requirements for the antenna system installation. The survey results identify types and quantities of materials; wiring provisions and requirements; access to facility for equipment, tools, and installation personnel; equipment layouts; and documentation requirements.

b. **Unpacking**. Unpack and inspect all materials and equipment to be installed.

c. **Antenna Tower/Pole Platform Location**. Antenna tower/pole platform structures are located at the RCF/VORTAC sites in accordance with design guidelines and requirements. This type of tower configuration is used to cause the least impact on the antenna pattern of the VORTAC radio equipment.

d. **Antenna Tower/Pole Platform Construction**. Construct the metal antenna tower or the non-metallic antenna pole and platform in accordance with Order 6510.7, Communications Antenna Support Towers.

e. **Coaxial Cable and Junction Box Installation**. Install the coaxial cable junction box on the metal antenna tower or the wood antenna pole and platform. Installation of coaxial cable from the RCF building to the antenna shall be either direct cable underground or overhead messenger cable support. The type of installation shall be determined by site requirements. Refer to figure 6-37 referenced in paragraph 195 for an illustration.

f. **Lightning Protection and Grounding**. Lightning protection and grounding shall be provided on all antenna support structures. See the Chapter 4, Figure 4-18, Antenna Tower Grounding and Lightning Protection, illustration.

g. **Antennas**. RCF antennas shall be installed on the antenna tower/pole platform utilizing a mounting mast attached to the platform. The mounting mast mates with the antenna mounting base. Refer to paragraph 197 for more illustrations.

190. **UNDERGROUND INSTALLATION OF COAXIAL CABLE**. Burial of cable in conduit provides increased reliability over direct burial. Cables shall be buried in accordance with specifications in FAA-C-1391, Installation and Splicing of Underground Cables.

a. **Cable Installation**. A pulling compound shall always be used to reduce friction and to avoid potential cable damage. The lubricant selected shall be compatible with the cable jacket. Soap-based lubricants are not recommended for polyethylene jackets as they may initiate stress cracking at some later date. Manufacturers of available compounds that are used with polyethylene jacketed cable include: Ideal Industries Incorporated (Aqua Gel), and American Polywater Corporation (Polywater J), or equal. Conduit shall be sealed and proper water drainage provided.

b. **Conduit Installation**. Conduit shall be installed to provide protection between the RCF building and tower/wood pole platform as shown in Figure 6-31, Cable Protective Conduit Installation.

191. **OVERHEAD INSTALLATION OF COAXIAL CABLE**. Overhead messenger cable support of RF coaxial cables between the RCF building and the antenna support structure shall be installed for short distances only (50 feet) and where trenching is impractical.

a. **Installation of Messenger Cable Supported Coaxial Cable**. The messenger cable shall be installed as parallel to the ground as possible. At a VORTAC site, the messenger cable shall not extend above the VORTAC counterpoise level. The messenger cable shall be attached to the building wall coaxial cable bulkhead plate and to the antenna support structure as shown in figure 6-25 and in Figure 6-32, Antenna Mast Messenger Cable Installation.

NOTE: Devices such as wind dampers and ice bridges shall be used in high wind and ice areas to protect the cable.

b. **Messenger Cable Tension**. The messenger cable manufacturer's recommended initial strand tensions shall never be exceeded. Strand and cable installation shall provide no more than a 1.5 percent sag as shown in Figure 6-33, Messenger Cable 1.5 Percent Sag at 70 Degrees Fahrenheit.

192. **RESERVED**.

FIGURE 6-31. CABLE PROTECTIVE CONDUIT INSTALLATION

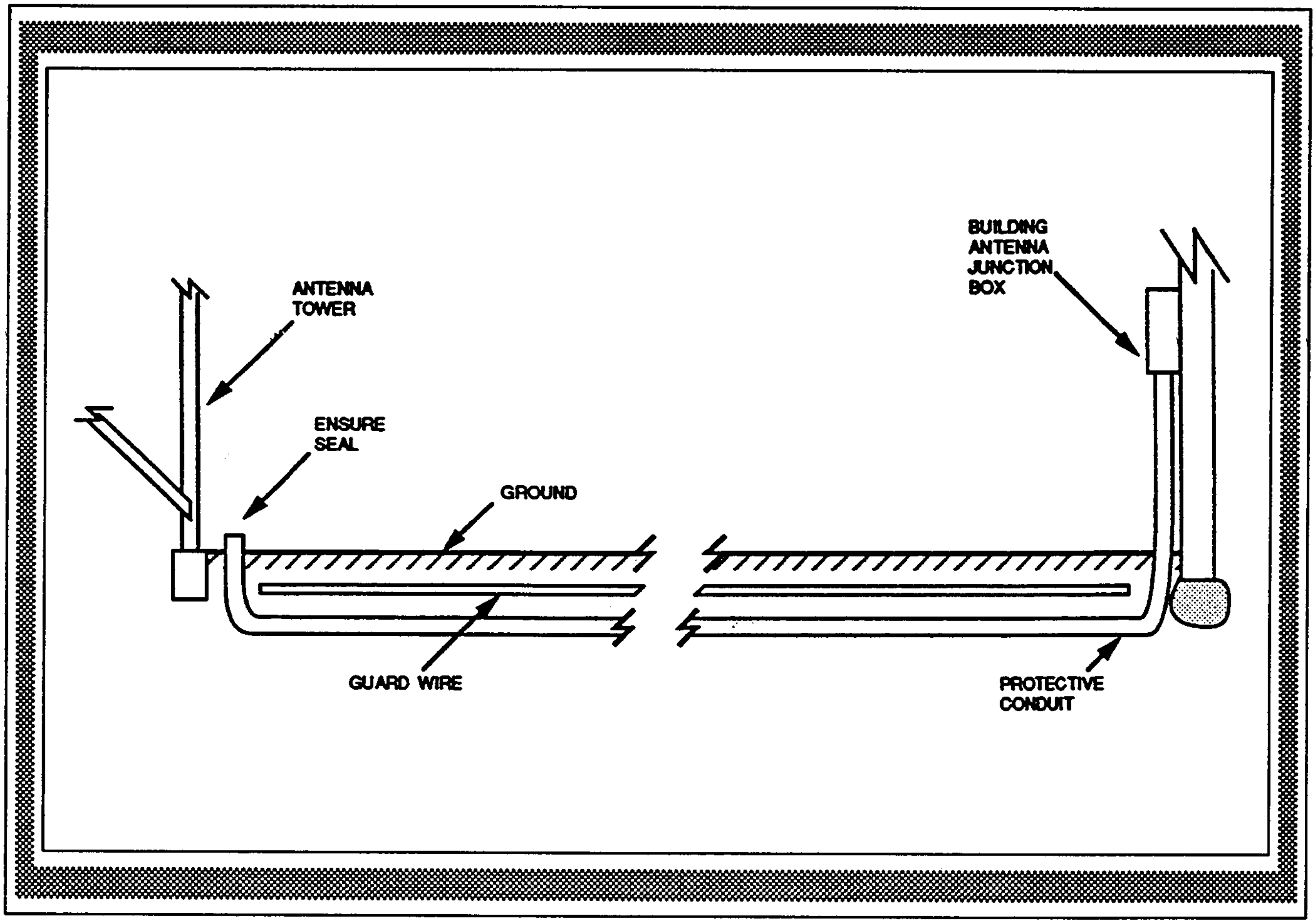


FIGURE 6-32. ANTENNA MAST MESSENGER CABLE INSTALLATION

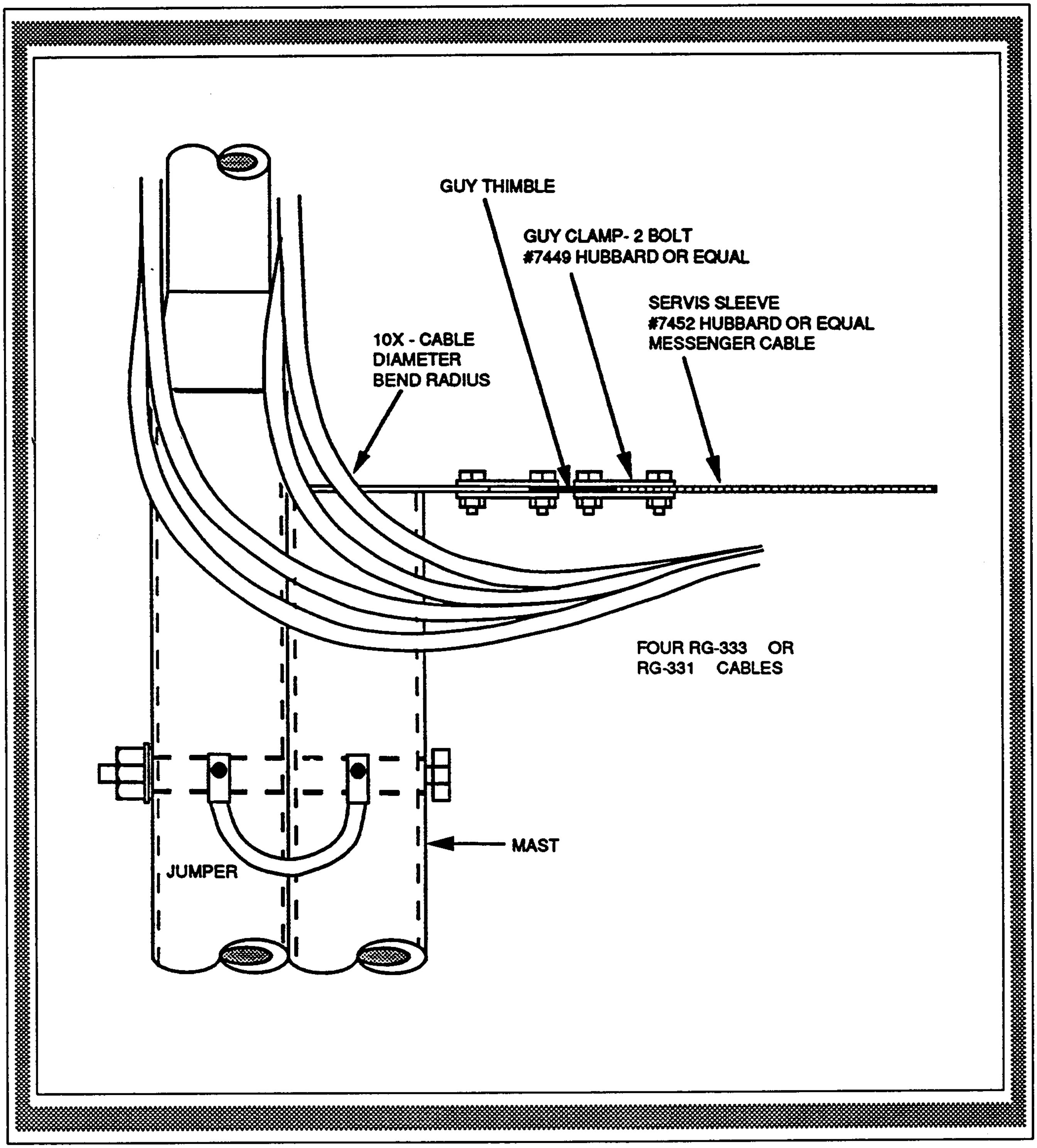
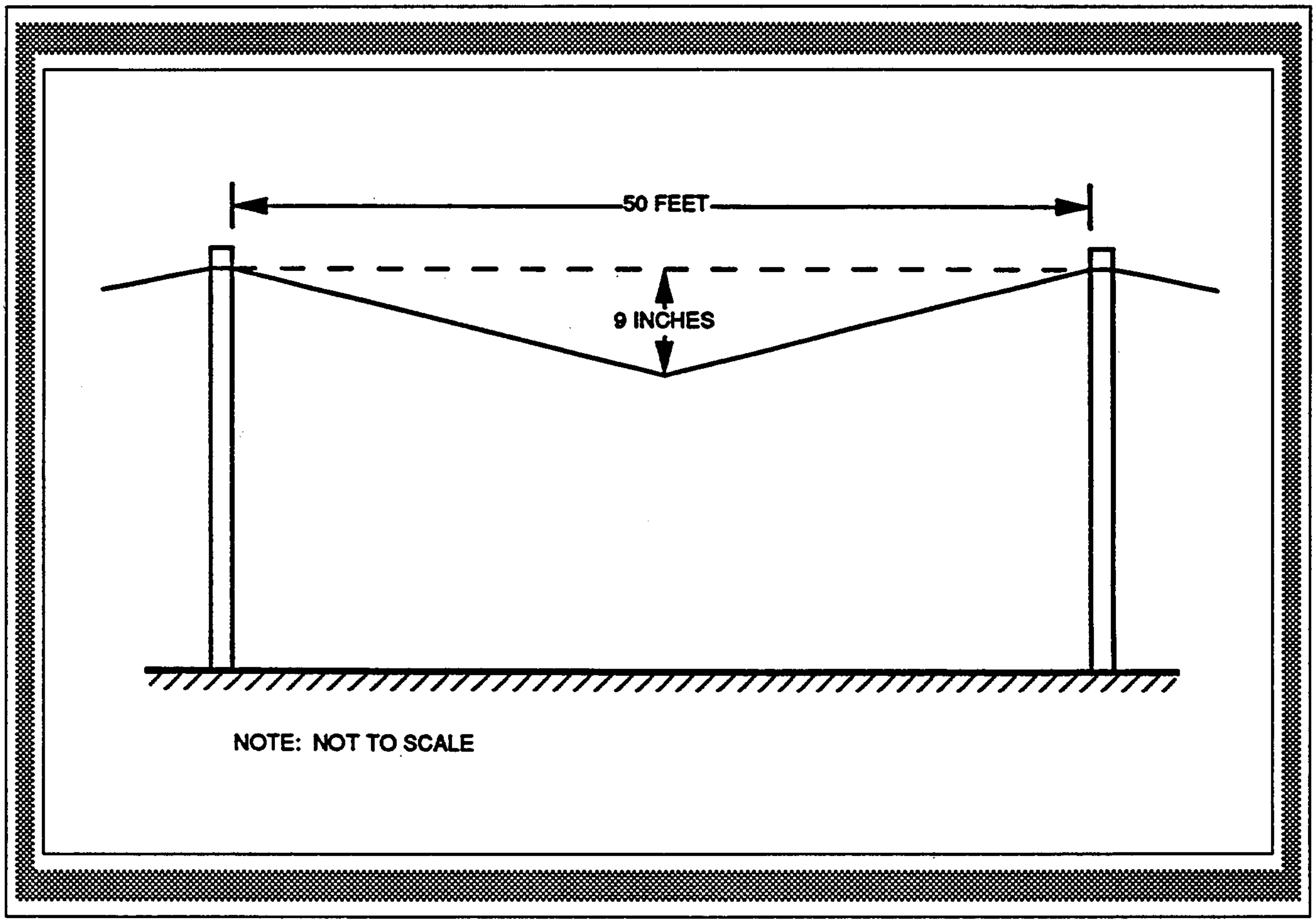


FIGURE 6-33. MESSENGER CABLE 1.5 PERCENT SAG AT 70 DEGREES FAHRENHEIT



SECTION 6. ANTENNA TOWERS AND POLES

193. **METAL ANTENNA TOWER**. Metal antenna support towers are normally procured by a national contract. The towers come in various heights and configurations, from 20 to 90 feet as described in Order 6510.7. Towers accommodate platforms with six swing-out mounts as shown in Figure 6-34, Typical VHF and/or UHF Antennas on Steel Tower. This configuration ensures 8 feet of separation between mounts. Since towers are procured in accordance with a performance specification, they may be provided in various configurations (triangular, square, and hexagonal).

a. **Regional Ordering Procedure**. Order 6510.7 outlines the current national contract and provides instructions to regions for ordering the towers from the contract. Metal tower assembly and installation instructions accompany each tower.

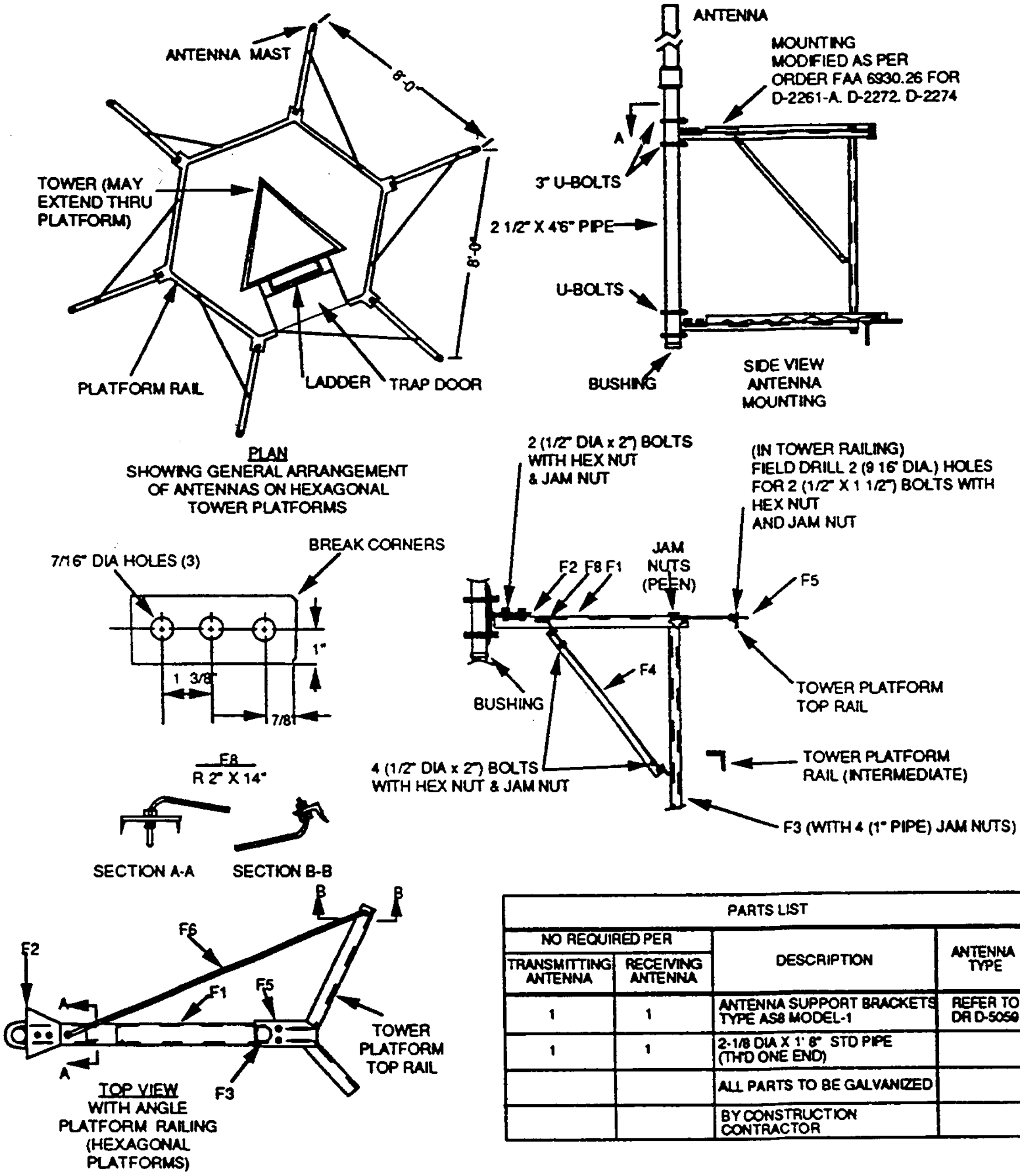
b. **Antenna Support Arm Change**. The antenna support brackets on most communications antenna support towers will not support the stacked version of VHF and UHF antennas. This is due to over stress caused by high winds and ice loading. The wind load, creating a bending force at the base of the antenna, may cause the horizontal bracket arm to fail. The horizontal bracket arm was modified and strengthened as shown in figure 6-34. Refer to Order 6930.26, Modify Antenna Support Arms on Communications Antenna Towers, for more details.

c. **Lightning Protection and Grounding**. Metal towers shall be provided with lightning protection and grounding in accordance with FAA-STD-019b and as illustrated in FAA Standard Drawings Series D-6075. A typical metal antenna tower lightning protection and grounding installation is shown in chapter 4, figure 4-14 and figure 4-18.

d. **Antenna Tower Height**. The standard minimum antenna tower height is 30 feet above average terrain. Greater heights are provided, as required, to overcome coverage restrictions due to shadowing by topography, buildings and trees. Towers with a height greater than 70 feet are designed with support guy wires. Towers can be designed to be self supporting structures when the height is under 70 feet. The exception to the latter is when the tower base has a small supporting frame. Support guy wires will be required. Refer to manufacturer specifications.

194. **ANTENNA POLE AND PLATFORM**. Non-metallic antenna pole and platform construction should be used at host radio navigational aid mountaintop facilities to minimize signal reflections and shadowing that may be caused by the metal antenna support structures.

FIGURE 6-34. TYPICAL VHF AND/OR UHF ANTENNAS ON STEEL TOWER



PARTS LIST

NO REQUIRED PER TRANSMITTING ANTENNA	NO REQUIRED PER RECEIVING ANTENNA	DESCRIPTION	ANTENNA TYPE
1	1	ANTENNA SUPPORT BRACKETS TYPE AS8 MODEL-1	REFER TO DR D-5050
1	1	2-1/8 DIA X 1' 8" STD PIPE (THD ONE END)	
		ALL PARTS TO BE GALVANIZED	
		BY CONSTRUCTION CONTRACTOR	

The platform height must not exceed navigational aid counterpoise height. A typical RCF site is shown in Figure 6-35, Typical RCF Antenna Pole Platform. Fiberglass antenna pole mounting as shown in Figure 6-38, Typical Region Supplied Let-Down Antenna Pole, may also be used in VORTAC facilities. Some sites experience long term high humidity causing a wet wood antenna pole "dielectric constant" to change by an order of magnitude. This change will affect VORTAC radiation patterns, as will snow and ice buildup. The application of this type of pole mounting shall be evaluated considering site location factors.

a. **Structure and Antenna Orientation**. Multiple antenna poles and platforms shall be aligned on a radial to the center of the VOR antenna array as shown in Figure 6-36, Typical VORTAC with RCF Antenna Pole Platforms. Multiple antennas mounted on a platform or cross arm shall also be aligned on a single radial to the center of the VOR antenna array.

b. **Lumber**. All lumber shall be seasoned Southern Pine, or Douglas Fir, No. 2 grade, or better. All wood poles shall be pressure treated prior to assembly with a non-metallic, non-conductive preservative. All lumber shall be coated with two coats of non-metallic, non-conductive paint.

c. **Lightning Protection and Grounding**. Lightning protection and grounding shall be provided for antenna poles and platforms in accordance with the FAA requirements as shown in FAA Standard Drawing Series, D-6075. See chapter 2, figure 2-9 for an illustration.

195. **ANTENNA TOWER COAXIAL CABLE AND JUNCTION BOX INSTALLATION**. Installation of antenna tower/pole platform coaxial cable and junction box shall be as follows:

a. **Antenna Tower Coaxial Cable Installation**. An illustration of a typical metal antenna tower coaxial cable installation is shown in sheet one and two of Figure 6-37, Typical Antenna Tower Coaxial Cable and Junction Box. Typical antenna platform coaxial cable conduit installation details are also shown in figure 6-37. Cables shall be attached to support members at 3-feet intervals or as close as possible while allowing the cable to give with member movement. Cable moisture drip loops shall be provided where applicable.

FIGURE 6-35. TYPICAL RCF ANTENNA POLE PLATFORM

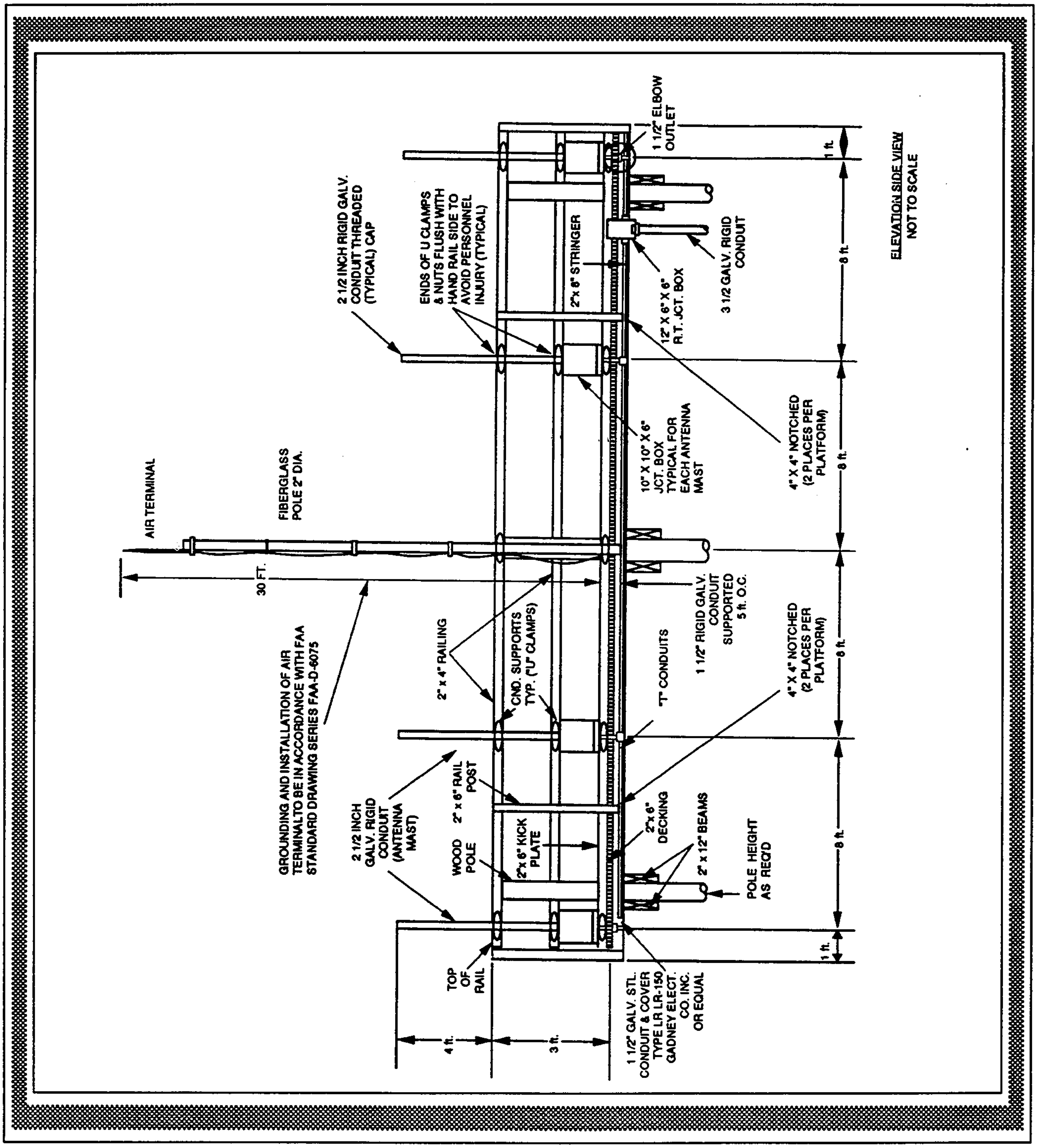


FIGURE 6-36. TYPICAL VORTAC WITH RCF ANTENNA POLE PLATFORMS

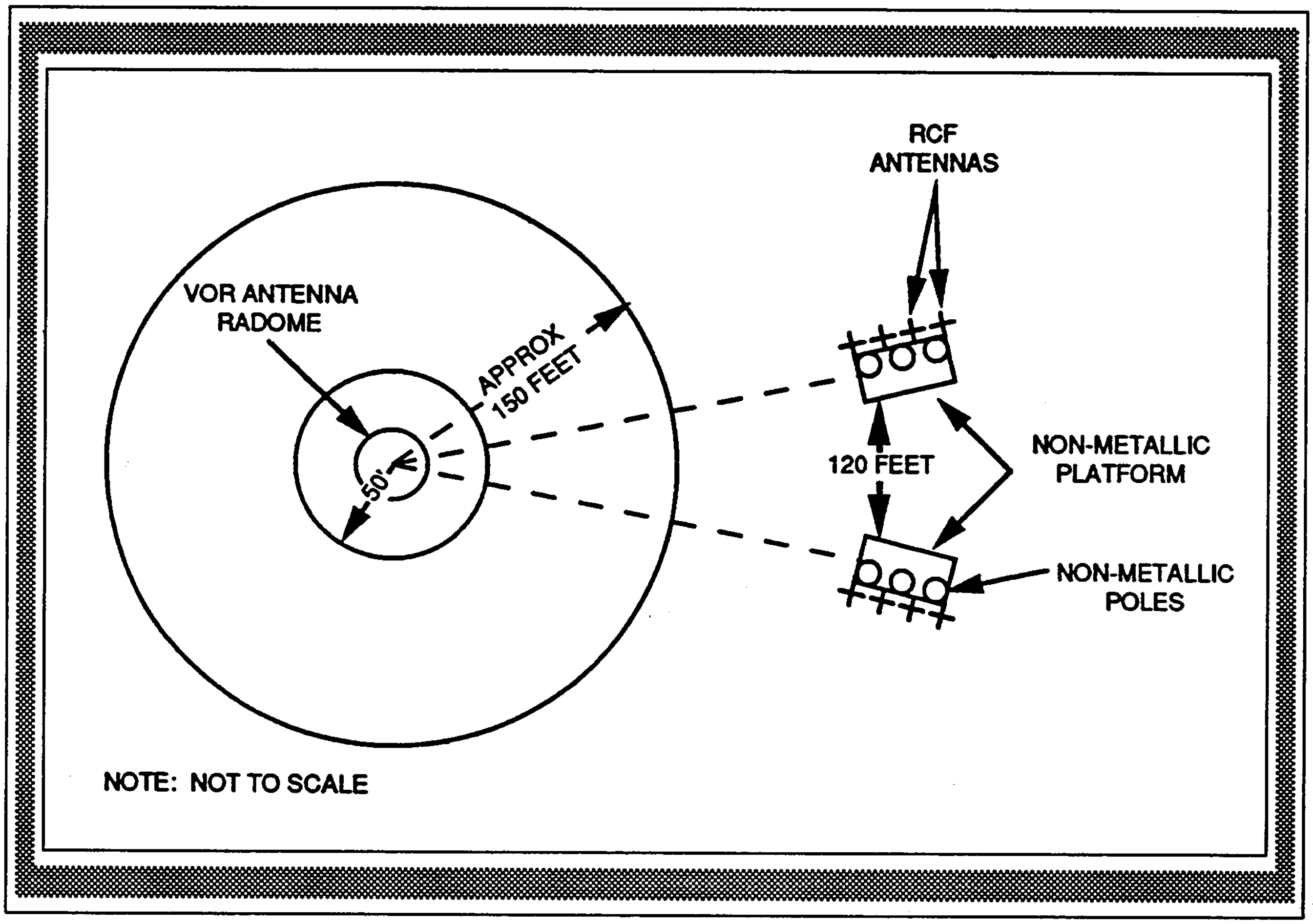


FIGURE 6-37a. TYPICAL ANTENNA TOWER COAXIAL CABLE AND JUNCTION BOX

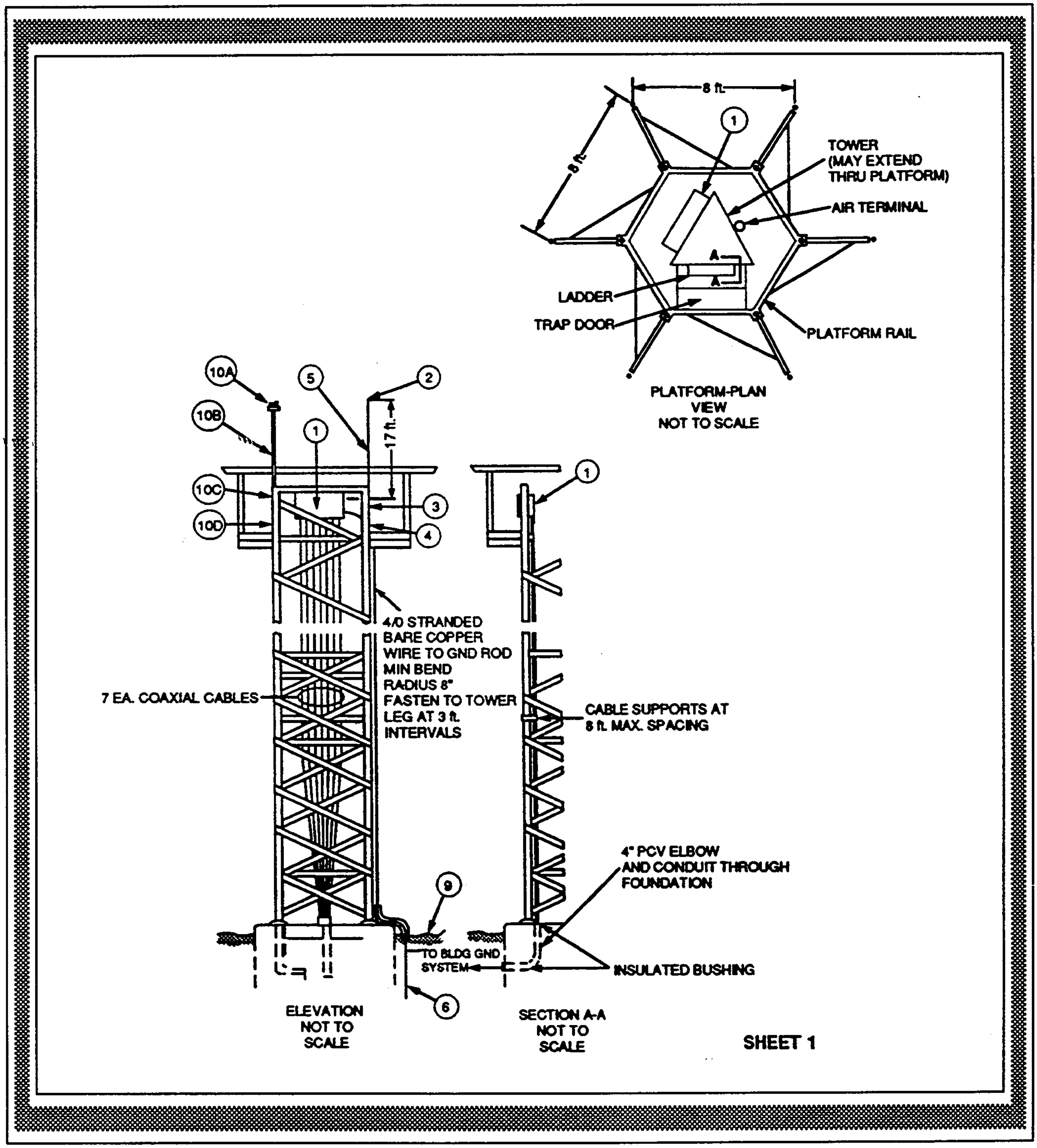
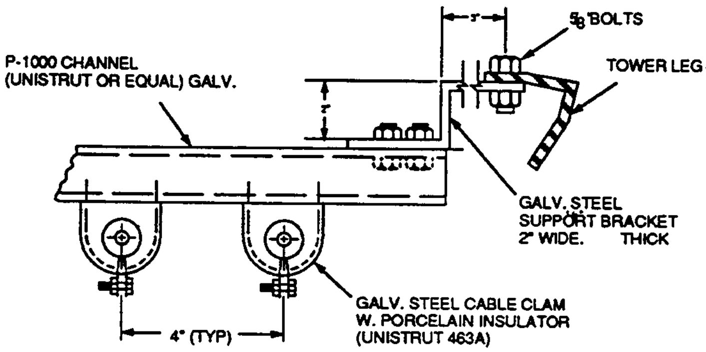
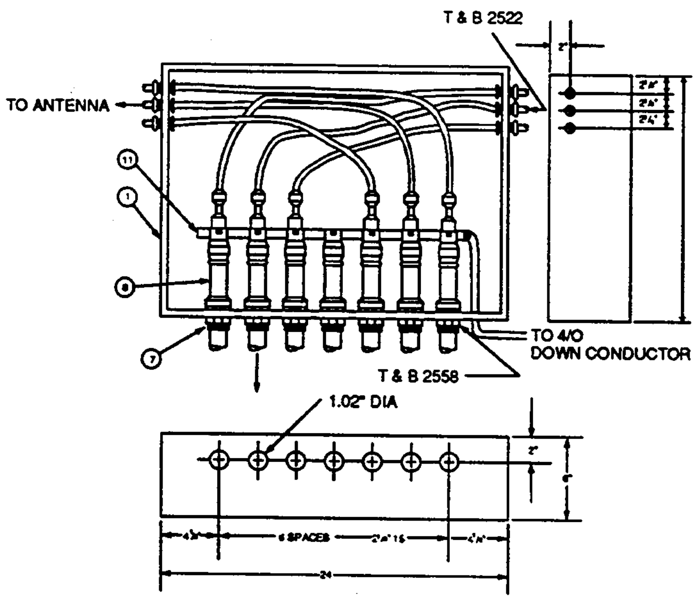


FIGURE 6-37b. TYPICAL ANTENNA TOWER COAXIAL CABLE AND JUNCTION BOX



CABLE SUPPORT DETAIL
NO SCALE



JUNCTION BOX
NOT TO SCALE

NOTES:

1. 24" x 20" x 6" DEEP WATERTIGHT JUNCTION BOX NEMA 12 (CIRCLE AW OR EQUAL). BOX TO BE SECURELY BOLTED TO TOP RAIL AND TO GALV. ANGLE IRONS.
2. AIR TERMINAL INSTALLATION IN THE CENTER OF THE TOWER. GROUNDING AND INSTALLATION OF THE AIR TERMINAL SHALL BE IN ACCORDANCE WITH FAA STANDARD DRAWING SERIES FAA-D-6075.
3. COPPER U-BOLT CLAMP (NO. 182, INDEPENDENT PROTECTION CO., OR APPROVED EQUAL).
4. 5/8" BRONZE SUPPORT BRACKET (NO. 67X. INDEPENDENT PROTECTION CO., OR APPROVED EQUAL.
5. 5/8"x8" COPPERWELD GROUND ROD THREADED TO MATCH AIR TERMINAL TIP AND BASIC BRACKET.
6. 3/4"x 10" COPPERCLAD GROUND ROD TIES TO ANTENNA GROUND AND BUILDING GROUND WITH A 4/0 AWG BARE COPPER WIRE.
7. CONNECTOR, WATERTIGHT WITH LOCKNUT (TYPE T & B 2558 OR EQUAL.
8. BRING CABLES INTO PATCH BOX. LEAVE 2 FEET OF EXCESS CABLE AND MAKE ENDS WATERTIGHT WITH TAPE.
9. PROVIDE CONCRETE VALVE BOX WITH COVER. TO MAKE GROUND CONNECTION POSSIBLE FOR INSPECTION MARK BOX COVER "GND".
10. IF OBSTRUCTION LIGHTING IS REQUIRED.
    A. OBSTRUCTION MARKER LIGHT, DOUBLE FIXTURE, CROUSE HINDS TYPE EOL, OR EQUAL
    B. 1" CONDUIT WITH THREADED END. EXTEND DOWN TOWER LEG AND THROUGH FOUNDATION.
    C. PHOTOELECTRIC CONTROL. CROUSE-HINDS TYPE PEC-4 OR EQUAL.
    D. GFI, 20A, 120 V, DUPLEX RECEPTACLE PASS & SEYMORE NO. 1591 OR APPROVED EQUAL IN WEATHERPROOF BOX
11. COPPER GROUND BAR WITH LUG IS SPECIAL MADE FOR SITE

SHEET 2

b. Antenna Platform Cable Junction Box Installation. The antenna tower or wood pole platform coaxial cable junction box shall be a weatherproof box installed on the railing of the metal tower platform, or the wood pole platform. This arrangement is shown in second sheet of figure 6-37. The cable transitions shall be located at a convenient height to effect necessary cable transfers. A junction box will in some cases be mounted on an antenna let-down pole below the hinge.

c. Junction Box Cable Installation. Sufficient cable slack shall be available inside the junction box on the antenna side of the coaxial cables to allow connection in any transition. Strain relief connectors, Thomas and Betts (T&B) type 2558 or equal on RG-333, T&B type 2544 or equal on RG-331 and T&B type 2522 or equal on RG-214, shall be installed where the cables enter the junction box as shown in the figure 6-37 illustration.

196. LET-DOWN MAST ANTENNA POLES. The typical let-down mast antenna pole shall be fabricated and supplied by the regions. A typical let-down mast antenna pole is illustrated in figure 6-38. The antenna support cross arms shall be aligned on a radial to the center of the array at a VOR site. This will minimize VOR far field course impact.

197. RCF ANTENNA MOUNTING AND GROUNDING.

a. Typical VHF and/or UHF Antenna Mounting. The typical VHF and/or UHF antenna mounting base is shown in detail A of Figure 6-39, Antenna/Mast Mounting Details. Detail B shows the mounting clamp which permits mounting on a 1.25 inch or a 2.50 inch mast. The clamp provides inline mounting with the mast, which allows feeding the antenna without exposing the transmission line coaxial connector. All installations may use a 2.50 inch support pipe.

b. Antenna Grounding. Grounding techniques differ among antennas. The outer conductor of both halves of each dipole of some antennas is at the same DC ground potential by design. A grounding lug is provided at the base of most antennas currently in use. A No. 2 AWG ground wire is recommended for attachment to the tower grounding down conductor or to the grounding down conductor on a non-metallic pole. Those antenna types that use the mount for grounding shall be mounted on a steel pipe. This pipe shall then be connected to the tower grounding down conductor.

198.-199. RESERVED.

FIGURE 6-38. TYPICAL REGION SUPPLIED LET-DOWN ANTENNA POLE

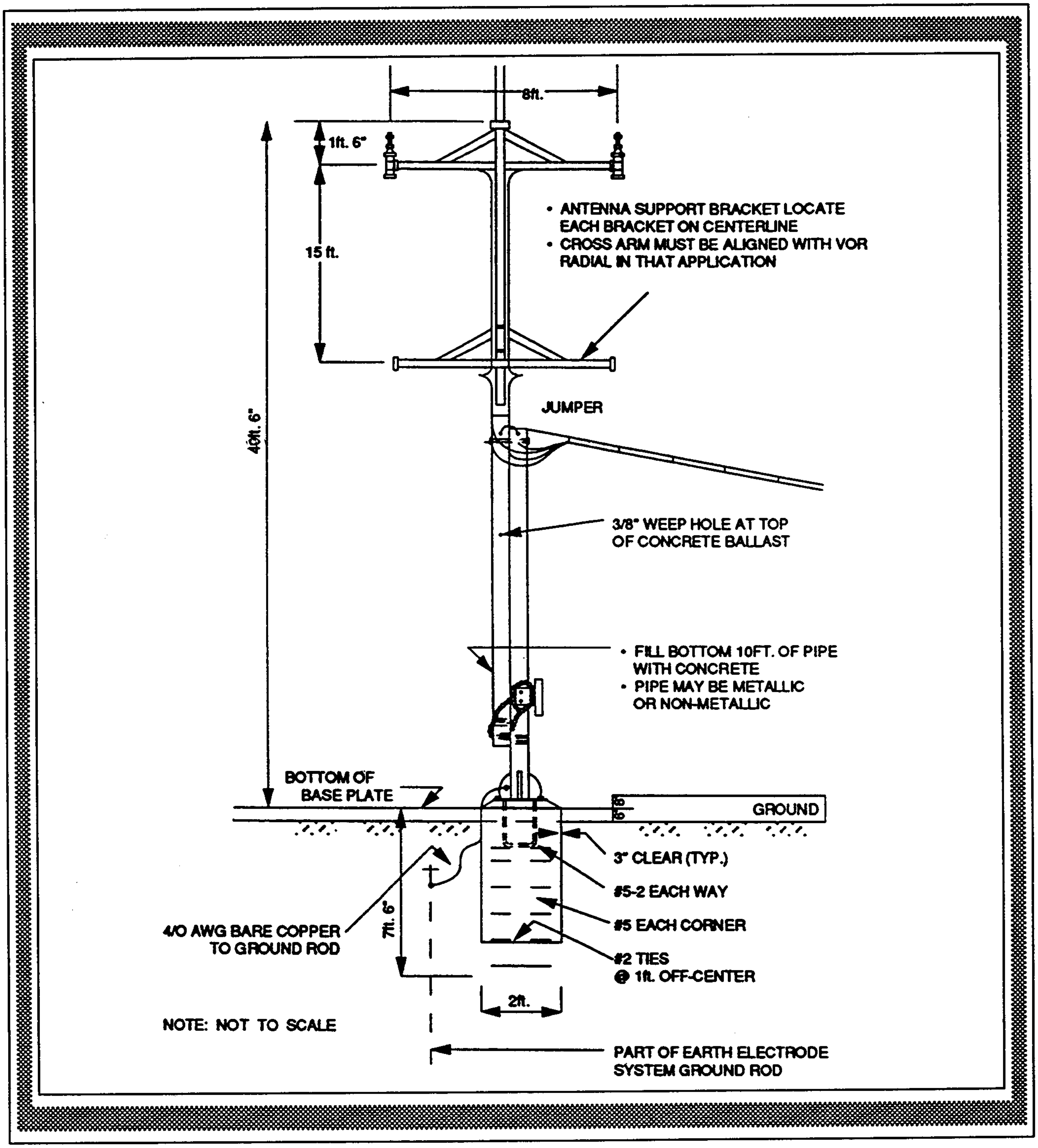
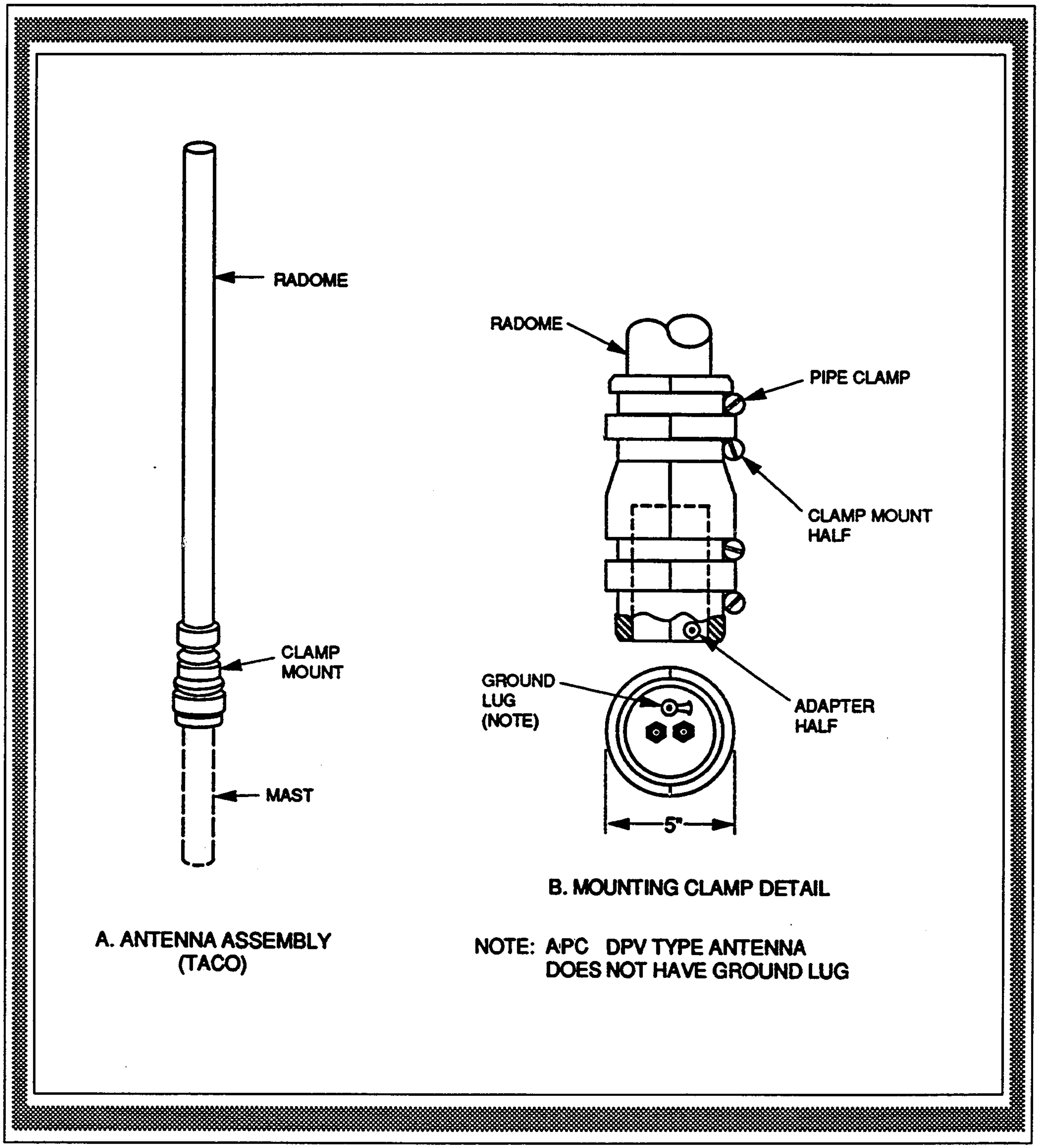


FIGURE 6-39. ANTENNA/MAST MOUNTING DETAILS



SECTION 7. BACKUP EMERGENCY COMMUNICATIONS (BUEC) EQUIPMENT

200. **INSTALLATION OF SITE BUEC EQUIPMENT**. The BUEC transceiver is a completely self-contained unit that may be mounted in a standard equipment rack. BUEC equipment shall be located away from the common digitizer equipment to avoid EMI when located at an ARSR facility. Equipment drawer slides shall be used to provide a means for inserting, supporting, and removing the transceiver from the rack as shown in Figure 6-40, BUEC Transceiver Slide Adapter Installation. The BUEC equipment rack shall provide forced air cooling. A "B" panel is required between units to avoid overheating of the units when more than one transceiver is located in the rack.

a. **BUEC Electrical and RF Connections**. Complete BUEC electrical and RF connections are described in the BUEC equipment instruction manuals TI 6610.4A, VHF Transceiver 20 Watt, TI 6610.10A, UHF Transceiver 20 Watt and TI 6650.17A, Remote Control Group. The BUEC system can utilize the standard RCF/Remote Center A/G Communications (RCAG) site equipment racks and the VHF/UHF antenna system. Refer to figure 6-40 for an illustration. A typical current BUEC antenna installation on a long-range radar antenna tower is illustrated in Figure 6-41, BUEC Antenna Location on Long Range Radar (LRR) Tower.

b. **Alternate Site Installations**. Individual site locations are determined by air traffic requirements for service volume air-ground communications coverage. This requirement can place BUEC equipment at remote locations. The only requirements are the near access of electrical power and a nearby two-wire TELCO landline connection. Most site locations will be installed in a standard 19-inch rack within a facility and use the facility antenna system. In some cases the BUEC equipment will be mounted in a closet-like space outside. In this configuration the equipment will be installed in a small weather proof lock-up type equipment enclosure on the ground as shown in Figure 6-42, BUEC Transceiver Stand-Alone Installation or with the same enclosure adjusted for mounting on a pole. The antenna tower can be steel or a non-metallic pole.

201.-206. **RESERVED**.

FIGURE 6-40. BUEC TRANSCEIVER SLIDE ADAPTER INSTALLATION

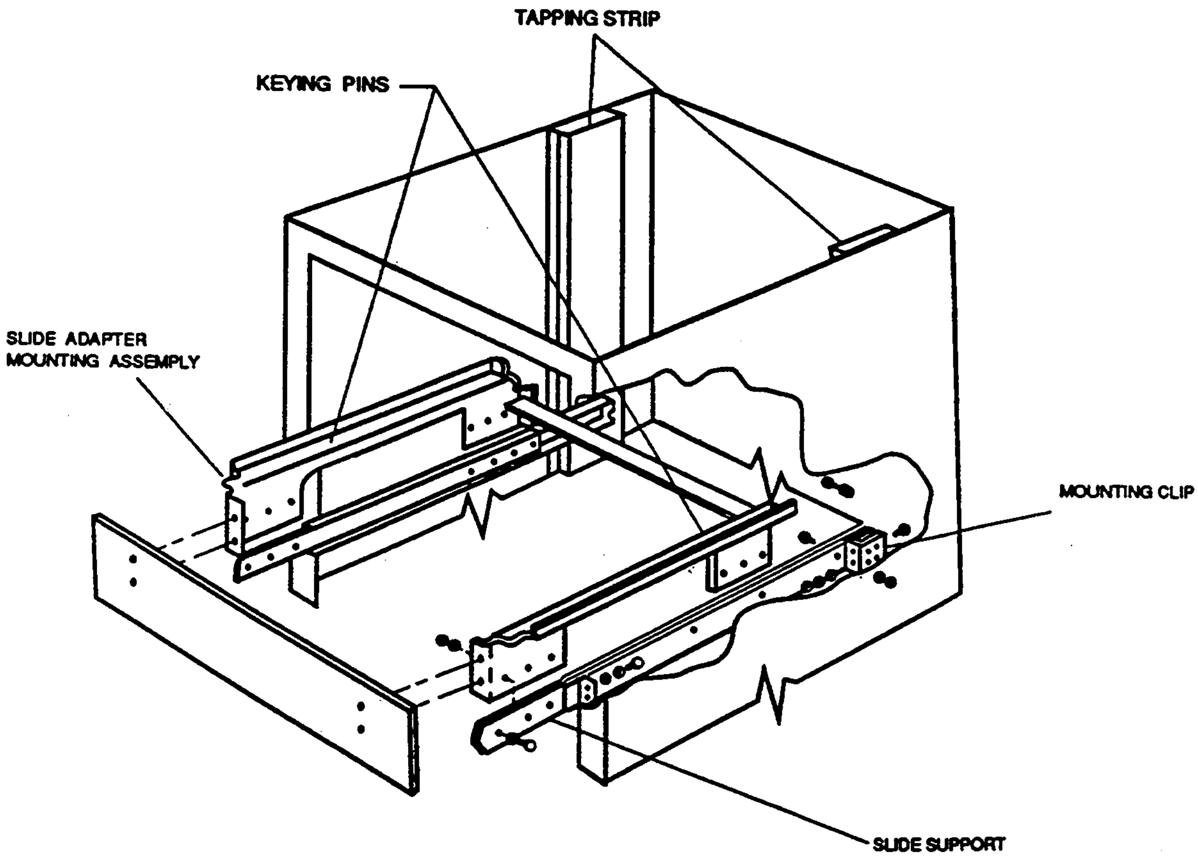


FIGURE 6-41. BUEC ANTENNA LOCATION ON LONG RANGE RADAR (LRR) TOWER

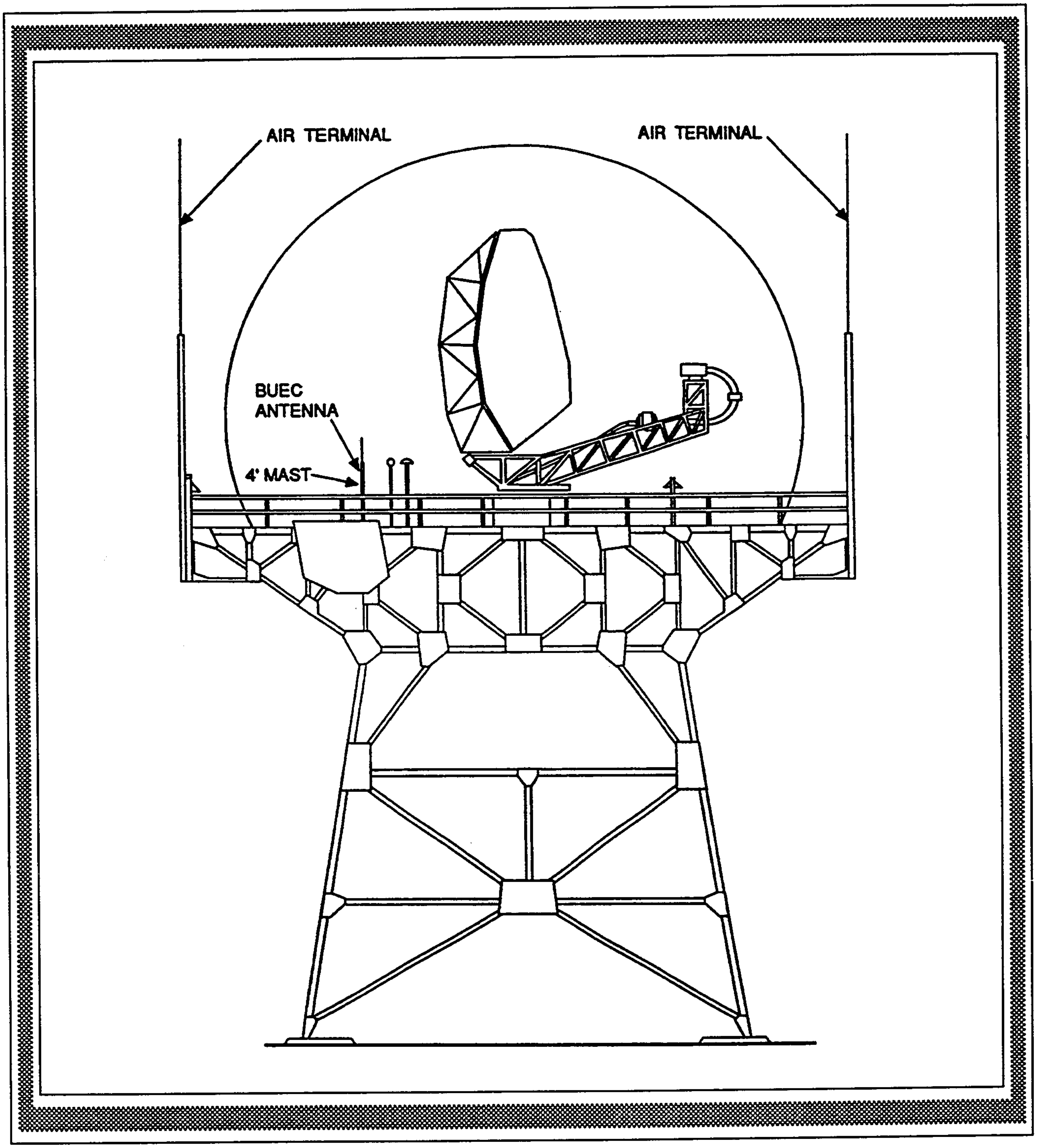
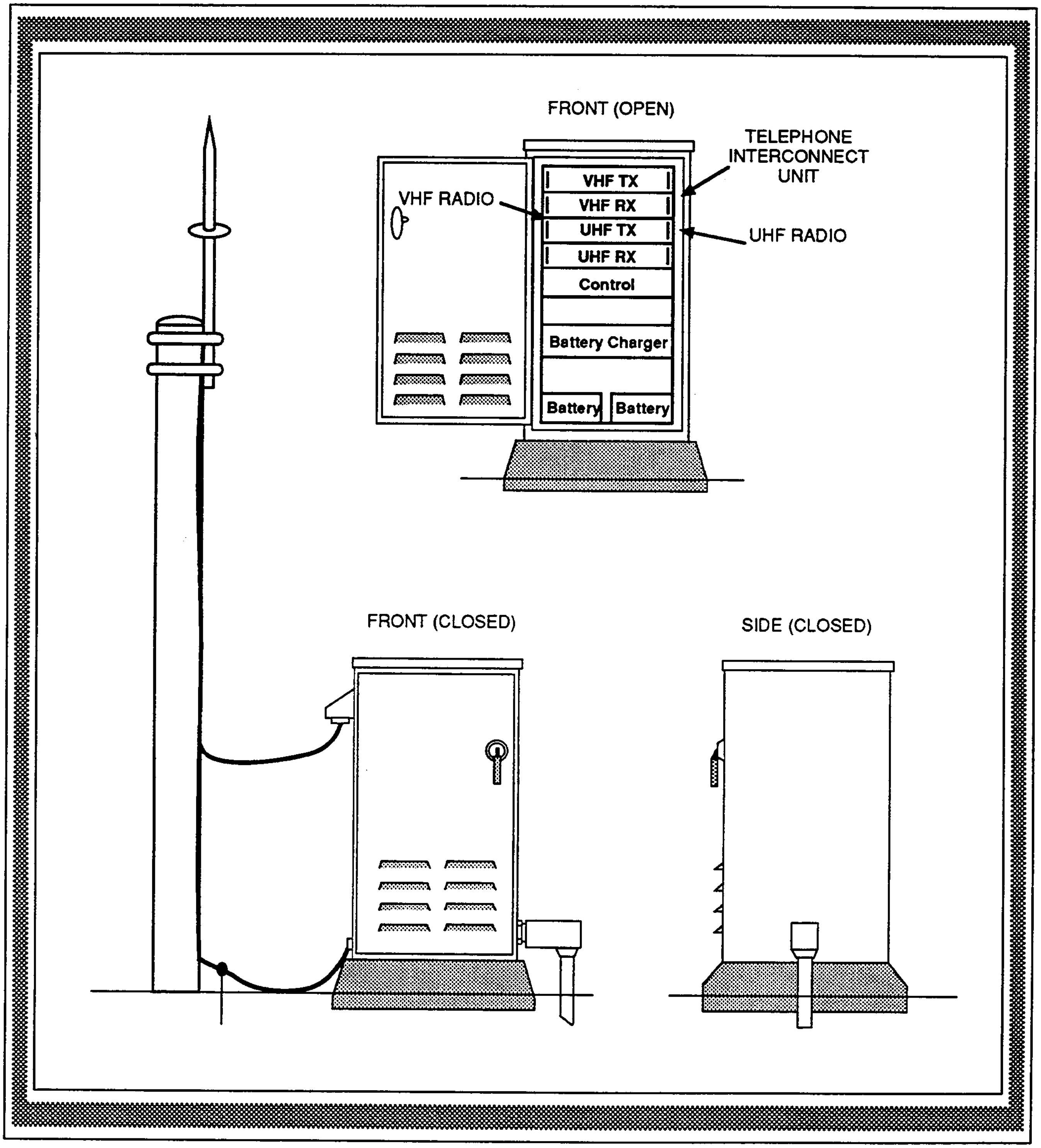


FIGURE 6-42. BUEC TRANSCEIVER STAND-ALONE INSTALLATION



CHAPTER 7. SYSTEM TEST AND ACCEPTANCE

SECTION 1. EQUIPMENT ACTIVATION, TEST AND CHECKOUT

207. **GENERAL**. This section describes the initial power up, check-out, and baselining of equipment at RCF's as part of the process associated with commissioning of a new site or restoration of a service provided by an established, relocated and/or collocated communications channel equipment. All equipment shall be activated and baselined for required operation as a separate task and will not be considered under system test.

208. **COMMUNICATIONS EQUIPMENT ACTIVATION**.

a. **Transmitters and Receivers**. The transmitters and receivers shall be tuned in accordance with RCF channel frequency requirements using procedures defined in the applicable equipment instruction manuals and maintenance handbooks.

b. **Transmitter Combiner Cavities**. The transmitter combiner cavities are factory tuned for a specific frequency; therefore, they should not require tuning. This tuning shall be checked and adjustments made for accuracy before system tests are begun.

c. **Receiver Multicouplers**. The receiver multicoupler circuits are broadband devices requiring no tuning. Refer to the equipment instruction manual and applicable orders if adjustment for unity gain is required.

d. **Voice Frequency Control System (VFCS)**. The VFCS interface equipment shall be adjusted as described in the equipment instruction manual to match manufacturer specifications and specific equipment requirements.

e. **Baseline Adjustments**. Equipment baseline adjustments shall be accomplished in all RCF site communications equipment before system test begins.

209. **BACKUP EMERGENCY COMMUNICATIONS EQUIPMENT CHECKOUT**. Make sure that the Backup Emergency Communications (BUEC) equipment at the control point is installed and performing properly. The control point is an ARTCC location in most applications and requires coordination to checkout BUEC equipment installed in a remote site. When BUEC equipment is installed in a remote site the following shall apply. The procedures are for one frequency of the system and shall be performed for each frequency that is authorized.

NOTE: The following tests will result in the actual transfer of the in-service equipment and must be coordinated with the system engineer and air traffic personnel. It is necessary at this time to arrange for a shutdown of the frequency being tested.

a. **BUEC Power Activation**. TURN ON the audio transfer panel that contains the transfer circuitry for the frequency to be tested.

b. **Control Facility Priority Module Selection**. Patch the desired transceiver outlet at the patch panel to the priority module of the control processor located in the facility. One jack in the 8 or 10 jacks provided on the priority module corresponds to the level of the priority assigned to the transceiver outlet for the particular radio position.

NOTE: The remote link, either landline or RCL, must be operational and connected at the RCF to an appropriate operational transceiver circuit that is activated, and must be in the REMOTE function position.

c. **Backup Selector SELECT Pushbutton**. Depress the corresponding backup SELECT pushbutton. The backup selector panel priority LED(s) will illuminate within a few seconds indicating the BUEC priority (i.e., facility) accessed. At the same time, the BUEC status board in the ARTCC equipment room will indicate the corresponding facility identifier. (If these conditions do not exist, the condition of the remote interfacility link or landline and the transceiver should be verified).

d. **Audio Transfer Relay and Keying Relay Operation**. The audio transfer relay in the audio transfer panel is actuated simultaneously with the illumination of the LED(s) indicator on the backup selector panel. This action switches the transmit and receive lines, push-to-talk keying circuit, keying interlock and transmitter control panel lamp from the normal communications equipment to the backup emergency communications equipment system. Verify the operation of the audio transfer relay and the keying relay from the operator radio position.

e. **Interface Voice Levels**. The priority modules for the remote control processor are designed and factory adjusted for operation with specified levels of transmit and receive voice grade inputs.

f. **Transmitter Input Audio Level**. Use required procedures for adjusting the landline levels between the ARTCC and the RCF to ensure compatibility with the landline interface of the RCF communications links. This procedure is described in the latest edition of Order 6470.29, Maintenance of En Route Air-to-Ground Communications

Facilities, and Order 6500.9A, Maintenance of BUEC Facilities. Verify that the primary communications interface is not degraded by the bypass relay in the audio transfer system.

g. **Landline Noise Check**. Landline noise levels in the audio bandwidth 300 to 3000 Hertz (Hz) shall not exceed current specifications as stated in Order 6000.22, Maintenance Of Two-Point Private Lines.

h. **Receiver Output Audio Level**. The landline audio received at the ARTCC from the RCF and applied to the processor interface is not level critical for proper operation. The actual level is a function of the transceiver audio output which is adjustable. The level in the interfacility interface is not degraded as a result of the bypass relay in the audio transfer system.

i. **Signal Losses**. In remote BUEC applications, signal losses in the audio bandwidth from 300 to 3000 Hz shall not exceed the specifications in Section 3 of Order 6000.22.

j. **Radio Communications Link (RCL) Audio Levels**. The RCL transmit and receive audio levels must be maintained within the range specified for the particular link used when the BUEC equipment is connected. The current version of Order 6540.5A, Maintenance of RCL Systems, shall be consulted and established tolerances observed.

k. **BUEC Documentation**. Complete all the initial performance and adjustment data entries on FAA Forms 6600-1, Transceiver Power Supply and Multimeter Reading; 6600-2, Antenna and Transmission Lines; 6600-3, Control Group Priority Module; 6600-4, Transceiver Transmit and Receiver Data; and 6600-5, Control Tone Generators and Power Supplies. The instructions for completing these forms are contained in the current version of Order 6600.2, Backup Emergency Communications (BUEC) Installation Instructions. The data are for historical purposes and legal records. Redline all applicable changes to the BUEC and host facility drawings.

210.-215. **RESERVED**.

SECTION 2. SYSTEM TEST

216. **GENERAL.** This section describes system tests to be completed before an RCF site is considered ready for system acceptance. The approach taken will be from a newly completed site where no integrated functional system test has been completed. Restoration of a service will take advantage of the applicable part of the full test plan. This discussion will describe what areas and what tests shall be performed. Test methods and quantities shall be coordinated by the site system test manager. Alignment, functional tests, internal performance tests and channelization for all equipment such as transmitter, receiver, combiner, multicoupler, and remote control equipment are to be completed before system test begins. This section will cover site landline input test through to RF carrier output test into the antenna. Refer to Chapter 6, Figure 6-1, RCF Electronic Equipment Block Diagram, as a general guide for what is to be tested. A communications facility test plan shall cover all equipment tests including power distribution under a separate heading.

a. **Alternating Current (AC) Power Test**. Site primary power to the load distribution board, facility electrical utilities lights, heating, cooling, and other accessories are part of the building structure. They will be separately tested and accepted under a separate facilities plan. Test of electrical distribution beyond the load center board is implemented under a communications equipment test plan. This plan shall verify that AC power is delivered properly to installed equipment. The checks to be made for AC power are listed in subparagraphs (1) through (5).

(1) Commercial AC service voltage is present and measured at the input to the AC load board.

(2) AC voltage shall be present and measured at each equipment rack with proper hot/neutral position on the outlet strip receptacle. Use a neon indicator type test plug and an AC voltmeter. Typical communications equipments supplied AC voltage in RCF sites are transmitters, receivers, multicouplers, VFCS interface, eliminator/charger inverters and test equipments.

(3) Main equipment circuit breaker group shall be separate from standby equipment circuit breaker group and shall be verified. Refer to Chapter 5, Figure 5-3, Typical Reconfigured Single Phase AC Panel Board, and Figure 5-4, Typical Reconfigured Three Phase AC Panel Board for guidance.

(4) All convenience AC outlets (maximum groups of three outlets) in equipment racks shall be assigned to a separate circuit breaker and shall not be provided in Direct Current (DC) voltage power equipment racks.

(5) A record shall be kept for each circuit breaker correlated with the designation for each equipment or rack it is assigned.

b. <u>DC Power Test</u>. Some RCF sites are equipped with a DC power source to provide DC voltage to equipment which normally operates from DC. Equipment which uses DC power as backup also is supported from this system. These sites will have a battery system and a battery eliminator/charger rack equipped with circuit breakers and a power distribution panel. The checks to be made for DC power are listed in subparagraphs (1) to (4).

(1) AC voltage is present and measured at the input to the battery eliminator/charger.

(2) DC voltage shall be present and measured at each equipment rack requiring DC power with properly identified terminations and wire color (red for positive voltage wire and black for negative/return wire). In the equipment connector the correct pin has a positive voltage and the negative/return pin connection is correct. DC voltage wiring shall not be connected to any ground termination.

(3) The main equipment circuit breaker group shall be separate from the standby equipment circuit breaker group.

(4) A record shall be kept for each circuit breaker correlated with the designation for each equipment or rack it is assigned.

c. <u>Transmit Antenna System Test</u>. RCF transmit antenna systems shall be tested for correct connectivity and VSWR. One of the transmitters connected to the antenna system will be used to test the selected antenna system. The RF line section mounted in the coaxial cable path with an appropriate indicator will be used to measure the antenna system performance. Local control of the transmitter shall be used with caution during this test to not interfere with other communications. In applications using combiners each of the four transmitters connected to the selected antenna system shall also be locally activated to verify their connectivity. Each transmit antenna system shall be tested using this or a similar approach. A record shall be kept for each transmit antenna system test performed indicating the designation for each system and the results of each test.

d. <u>Receive Antenna System Test</u>. RCF receive antenna systems shall be tested for correct performance and connectivity. The receive antenna selected will be temporarily connected to a transmitter RF line section output port for this test. The receive antenna cable will be disconnected at the transfer relay connection point or the output point of the multicoupler. Local control of the transmitter will provide an RF energy source to measure the receive antenna system performance. Each receive antenna shall be tested using this approach or similar approach. Receiver connectivity shall be tested by injecting an appropriate receiver frequency signal into the port where the receiver cable was removed above. A headset/speaker set will be used at the receiver as an indication that a modulated RF signal is present at the antenna cable port. Each receiving antenna system connectivity shall be tested using this or a similar approach. A record shall be kept for each receive antenna system test performed indicating the designation for each system and the results of each test.

e. **Landline Path Test**. RCF facilities in most cases are connected to other facilities with four-wire landlines. Landlines terminated at the facility TELCO block are tested and accepted separately. The communications equipment installation plan will complete the interior work to the VFCS control equipment. When the installation is complete, each channel pair shall be tested and the results documented to verify connectivity from the landline termination block through the FAA demarc box suppressors or mini-demarc system to each channel VFCS control equipment connector. Injection of a tone at the termination block individual pair and detection at the destination is a suggested verification technique. One pair is used for "transmit only" audio/signaling and one pair is used for "receive only" audio/signaling. A record shall be kept for each wire pair with correlation for each equipment or rack to which it is assigned.

f. **VFCS Control Test**. Each RCF channel is equipped with a VFCS interface equipment. Verification test will be made from the landline termination block through the interface equipment to the RF equipment audio and control input or output connector. All VFCS signaling channels will be checked for proper operation and proper tolerances. Refer to the equipment technical instruction books and FAA maintenance handbooks for more precise information and procedures. A record shall be kept for each channel VFCS interface equipment test correlating the designation of each equipment or rack to which it is assigned.

217.-220. **RESERVED**.

SECTION 3. SYSTEM ACCEPTANCE

221. **GENERAL**. This section provides a brief description of the events associated with the acceptance of a new site, or acceptance for restoration of a service provided by an established, relocated, and/or collocated communications channel.

222. **CONTRACTOR ACCEPTANCE INSPECTION**. The CAI is an acceptance inspection between the TOR and the contractor that certifies the work accomplished by the contractor. Discrepancies found during this inspection are the responsibility of the contractor for correction. The contractor is relieved of obligation concerning the work after the CAI is signed.

223. **JOINT ACCEPTANCE INSPECTION**. The JAI is an inspection required between the TOR and the Airway Facilities representative prior to the commissioning and/or return to service of an established, relocated, and/or collocated communications channel in accordance with Order 6030.45, Facility Reference Data File.

a. **Joint Acceptance Inspection Report Checklist**. The JAI report cover sheet and associated six-page JAI report checklist are representative of data required for each RCF CAI and JAI. Order 6030.45 provides further guidance and distribution requirements for the report.

b. **Joint Acceptance Inspection Report Exceptions List and Clearance Record**. The JAI exceptions list and clearance record report list all exceptions from the JAI checklist and the status of each exception. All noted major exceptions must be resolved prior to the commissioning or restoration of service, provided that the exceptions do not violate existing applicable agency orders, technical instruction manuals, or accepted standard practices.

224. **TECHNICAL REFERENCE DATA**. FAA Form 6030-16, Technical Reference Data Records Cover/Transmittal Sheet, and FAA Form 6030-17, Technical Reference Data Record, are used as a representative documents to record the initial performance of all RCF facility systems and equipment. Instructions for completing the forms are contained in the current version of Order 6030.45.

225. **TECHNICAL PERFORMANCE RECORD**. The current version of FAA Form 6600.6, Technical Performance Record, VHF/UHF Air/Ground Receiver/Transmitter, is filled out in accordance with the current version of Order 6000.15, General Maintenance Handbook for Airway Facilities, to indicate the initial readings. The initial parameters to be recorded are identified in Order 6580.5, Maintenance of Remote Communications Facility Equipment.

226. **FLIGHT INSPECTIONS**. Flight inspections should be done to verify the operational performance of an A/G communications RCF facility. The instructions for flight inspection are contained in FAA Handbook OA-P-8200.1, United States Standard Flight Inspection Manual. The regions are encouraged to determine the initial coverage of each relocated and/or collocated communications channel. Portable regional

or Washington headquarters-supplied field intensity evaluation equipment shall be used in an FAA, military, or rental aircraft. The measurements shall be related to a computer analysis for critical coverage distances and elevations in both VHF and UHF aeronautical frequency bands.

227. **SITE CLEANUP**. The FAA or contractor electronics installation staff shall remove all packing boxes and other litter resulting from the installation work. It shall be the responsibility of the installation staff after the work is completed to ensure that all excess equipment and abandoned cables are cleared from the site.

228.-235. **RESERVED**.

APPENDIX 1. ACRONYMS

AC	Alternating Current
ADAS	AWOS Data Acquisition System
AFSS	Automated Flight Service Station
AMPS	Amplifiers
ARSR	Air Route Surveillance Radar
ARTCC	Air Route Traffic Control Center
ARTS	Automated Radar Terminal System
ASOS	Automated Surface Observing System
ASR	Air Surveillance Radar
ATC	Air Traffic Control
ATCT	Airport Traffic Control Tower
ATIS	Automated Terminal Information System
AWG	American Wire Gage
AWOS	Automated Weather Observing System
A/G	Air-to-Ground
BRITE	Bright Radar Indicator Terminal Equipment
BUEC	Backup Emergency Communications
CAI	Contractor Acceptance Inspection
CIP	Capital Investment Plan
CM	Centimeter
dB	decibel
dBi	decibel, Relative to an Isotropic Source
dBm	decibel relative to 1 microvolt
DBRITE	Digital Brite Radar Indicator Terminal Equipment
DC	Direct Current
EFAS	En Route Flight Advisory System
EIS	Environmental Impact Statement
EIA	Electronic Industry Association
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EMP	Electromagnetic Pulse Interference
EMT	Electrical Metallic Tubing
ERMS	Environmental Remote Monitoring Subsystem
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FONSI	Finding of No Significant Impact
FSK	Frequency Shift Keying
FSS	Flight Service Station
F&E	Facilities and Equipment
GCA	Ground Controlled Approach
GHz	GigaHertz
HF	High Frequency
HVAC	Heating, Ventilation, and Air Conditioning
Hz	Hertz
IFR	Instrument Flight Rules
IM	Intermodulation

JAI	Joint Acceptance Inspection
kHz	KiloHertz
LB	Elbow Fitting
LPA	Linear Power Amplifier
MCM	One Thousand Circular Mils Cross Sectional Area
MDT	Maintenance Data Terminal
mho	mho (unit of conductance)
MHz	MegaHertz
MIL	Military
MIL-STD	Military Standard
Mini-demarc	Miniature Demarcation Console
MT	Maintenance Terminal
M/S	Main/Standby
NAS	National Airspace System
NAVAID	Navigational Aid
NEC	National Electrical Code
NFPA	National Fire Protection Association
NOTAM	Notice to Airmen
NTIA	National Telecommunications & Information Administation
PTT	Push-to-Talk
PVC	Polyvinyl Chloride
RCAG	Remote Center A/G Communications
RCF	Remote Communications Facilities
RCL	Radio Communications Link
RCO	Remote Communications Outlet
RCT	Remote Control Terminal
RF	Radio-Frequency
RFI	Radio-Frequency Interference
RMMS	Remote Maintenance Monitoring System
RTR	Remote Transmitter Receiver
RX	Receiver
SAD	Site Adaptation Data
STD	Standard
T&B	Thomas & Betts
TACAN	Tactical Aid to Navigation
TELCO	Telephone Company
TOR	Technical Onsite Representative
TRACON	Terminal Radar Approach Control
TX	Transmitter
T/R	Transmit/Receive
UHF	Ultra High Frequency
UL	Underwriters Laboratory
US	United States

V	Volts
VAC	Volts Alternating Current
VDC	Volts Direct Current
VFCS	Voice Frequency Control System
VHF	Very High Frequency
VODATA	Voice Data System
VOR	VHF Omnidirectional Range
VORTAC	VOR with TACAN
VSWR	Voltage Standing Wave Ratio
W	Watt

APPENDIX 2. REFERENCES

In addition to equipment manuals, the following documents are referenced in this order. In each case the latest issue in effect at the time of issuance shall take precedence over the contents of this order.

1. **FAA Specifications**.

Number	Title
FAA-C-1217	Electrical Work, Interior
FAA-C-1391	Installation and Splicing of Underground Cable
FAA-E-2072	Cable, Telephone, Exterior
FAA-E-2672	Racks, Cabinet, Solid-Sided, and Open-Sided Types
FAA-STD-019b	Lightning Protection Grounding, Bonding, and Shielding Requirements of Facilities
FAA-STD-020b	Transient Protection Grounding, Bonding, and Shielding Requirements for Equipment

2. **FAA Orders and Handbooks**.

3900.19	Occupational Safety
4660.1	Real Property Handbook
6000.15	General Maintenance Handbook for Airway Facilities
6000.22	Maintenance of Two-Point Private Lines
6030.45	Facility Reference Data File
6050.32	Manual of Regulations and Procedures for FAA Spectrum Management
6470.29	Maintenance of En Route Air/Ground Communications Facilities
6480.4	Airport Traffic Control Tower Siting Criteria

6480.6	Maintenance of Terminal Air/Ground Communications Facilities
6500.9A	Maintenance of Backup Emergency Communications (BUEC) Facilities
AF P 6500.19	Communications Facilities and Equipment Modification Handbook - General
6510.4	Radio Communications Requirements for Air Traffic Control Facilities
6510.7	Communications Antenna Support Tower
6540.5A	Maintenance of Radio Communications Link (RCL)
6580.5	Maintenance of Remote Communications Facility (RCF) Equipments
6600.2	Backup Emergency Communications (BUEC) Installation Instructions
6600.6	Technical Performance Record
6610.3	Power Output Limitation: FSS, Terminal and Low Altitude En Route VHF and UHF Transmitters
6630.23	General Communications Handbook
6630.3	Antenna Configuration Handbook for Terminal and En Route Facilities
6630.5	Terminal Communications Installation Standards Handbook
6930.26	Modify Antenna Support Arms on Communications Antenna Towers
6950.19	Practices and Procedures for Lightning Protection, Grounding, Bonding, and Shielding Implementation
6950.20	Fundamental Consideration of Lightning Protection, Grounding, Bonding, and Shielding
6960.1	Sanitary Systems in FAA Facilities

7210.3	Facility Operation and Administration
OA-P-8200.1	FAA U.S. Standard Flight Inspection Manual

3. **Commercial Documents**.

NFPA 70	National Fire Protection Association Title 70, National Electrical Code Articles 200 through 280, Grounding and Surge Protection
NFPA 78	National Fire Protection Association Title 78, Lightning Protection Code
UL 96A	Installation Requirements for Lightning Protection Systems

APPENDIX 3. EQUIPMENT SPECIFICATIONS

1. PURPOSE. This appendix contains listings of typical specifications for equipment items used in RCFs.

2. EQUIPMENT CATEGORIES. Table 1 identifies the A/G radio communications equipment categories, lists the equipment items covered under each category, and indicates the appropriate table that contains details of each equipment.

3. EQUIPMENT SUMMARIES. Tables 2 through 14 present physical and electrical characteristics and performance specifications for the A/G radio communications equipment items currently used. The tables permit comparison and evaluation of installation criteria and performance. These are intended for use by planning, design, installation, and maintenance personnel.

4.-5. RESERVED.

TABLE 1. EQUIPMENT CATEGORIES

CATEGORY	EQUIPMENT	REFERENCE TABLE
VHF Receivers	AN/GRR-23 (or equal)	Table 2
UHF Receivers	AN/GRR-24 (or equal)	Table 3
VHF Transmitters	AN/GRT-21 (or equal)	Table 4
UHF Transmitters	AN/GRT-22 (or equal)	Table 5
VHF Receivers (new)	FA-10452 (or equal)	Table 6
UHF Receivers (new)	FA-10453 (or equal)	Table 7
VHF Transmitters (new)	FA-10450 (or equal)	Table 8
UHF Transmitters (new)	FA-10451 (or equal)	Table 9
ANTENNA ELECTRICAL CHARACTERISTICS		
VHF	TACO-D-2276	Table 10
	APC-DPV35	Table 10
VHF/VHF	TACO-D-2722	Table 10
	APC-DPV36	Table 10
UHF/UHF	TACO-D-2274	Table 10
	APC-DPV38	Table 10
UHF/VHF	TACO-D-2273	Table 10
	APC-DPV39	Table 10
UHF	TACO-D-2277	Table 10
	APC-DPV37	Table 10
VHF, 4 dBi gain	TACO-D-2261A-1	Table 10
	APC-DPV40, DPV40B	Table 10

TABLE 1. EQUIPMENT CATEGORIES (CONT')

CATEGORY	EQUIPMENT	REFERENCE TABLE
VHF, 10 dBi gain (Yagi)	TACO-Y102B-130V APC-YG-118	Table 10 Table 10
ANTENNA PHYSICAL CHARACTERISTICS		
VHF	TACO-D-2276 APC-DPV35	Table 11 Table 12
VHF/VHF	TACO-D-2722 APC-DPV36	Table 11 Table 12
UHF/UHF	TACO-D-2274 APC-DPV38	Table 11 Table 12
UHF/VHF	TACO-D-2273 APC-DPV39	Table 11 Table 12
UHF	TACO-D-2277 APC-DPV37	Table 11 Table 12
VHF, 4 dBi gain	TACO-D-2261A-1 APC-DPV40, DPV40B	Table 11 Table 12
VHF, 10 dBi gain (Yagi)	TACO-Y102B-130V APC-YG-118	Table 11 Table 12

TABLE 2. VHF RECEIVERS (TYPICAL CHARACTERISTICS)
(Sheet 1)

EQUIPMENT CHARACTERISTICS AN/GRR-23	DESCRIPTION	IDENTIFICATION
Equipment Supplied	VHF Receiver, E/W (Optional)	Single Frequency Oscillator Synthesizer
Prime Power	105, 120, 210 & 240 ±10%	AC Volts
	Single	AC Phase
	47-420 Hertz 22-30 (Alt)	AC Frequency DC Volts
	50 Watts	Power
Dimensions	3 1/2 Inches	Height
	19 Inches	Width
	12-1/4 Inches	Depth
Weight	38 Pounds	Crated
	22 Pounds	Uncrated
Frequency Range	116.00-149/ 149.975^{n}	MHz
No. of Channels	one	Quantity
Tuning Increments	50/25^{n}	kHz
Type of Receiver	Single	Conversions
IF Frequency	20.6 MHz	1st IF Freq.
	N/A MHz	2nd IF Freq.
Frequency Stability	0.002/0.001^{n}	Percentage (Long Term)

TABLE 2. VHF RECEIVERS (TYPICAL CHARACTERISTICS) (CONT'D)
(Sheet 2)

EQUIPMENT CHARACTERISTICS AN/GRR-23	DESCRIPTION	IDENTIFICATION
Type Freq. Control	Quartz Crystal Synthesized	Description
	CR75/1	Type
	HC-6/U	Holder Type
Local Osc. Crystal	68.3/85.275 MHz	Frequency Range
	$F_c = \frac{F_r + 20.6}{2}$	Frequency Calculation
	0.0005 ppm	Crystal Tol.
Emission	A3E	Modulation Type
Receiver Output	Watts 0.1 0.1	Level Output 1 Output 2
	Ohms 600 600	Impedance Output 1 Output 2
Sensitivity	3.0 μV	at 10 dB (S+N)/N at 30% and 5% Modulation with a 1000 Hz Tone 0.1 Watts Output
Selectivity	$\pm$ 18/10^n kHz	@ 6dB Bandwidth
	$\pm$ 40/25^n kHz	@ 80dB Skirt BW
Automatic Volume Control (AVC)	6 μV to 1.0V Input Ranging	Audio Output Constant within 3 dB for Signal
	30 dB	Muting Range

TABLE 2. VHF RECEIVERS (TYPICAL CHARACTERISTICS) (CONT'D)
(Sheet 3)

EQUIPMENT CHARACTERISTICS AN/GRR-23	DESCRIPTION	IDENTIFICATION
Squelch Circuit	3.0 μV 50 μV	At Max RF Gain At Min RF Gain
Audio Response	+1, -2 dB	Level, Variation (300-3000 Hz)
Harmonic Distortion	10%	At 30% Mod.
	20%	At 90% Mod.
Notes:	^{n} Figures for 25 kHz Spacing	

TABLE 3. UHF RECEIVERS (TYPICAL CHARACTERISTICS)
(Sheet 1)

EQUIPMENT CHARACTERISTICS AN/GRR-24	DESCRIPTION	IDENTIFICATION
Equipment Supplied	UHF Receiver, E/W (Optional)	Single Frequency Oscillator Synthesizer
Prime Power	105, 120, 210 & 240 ±10%	AC Volts
	Single	AC Phase
	47-420 Hertz 22-30 (Alternate)	AC Frequency DC Volts
	50 Watts	Power
Dimensions	3-1/2 Inches	Height
	19 Inches	Width
	12 1/4 Inches	Depth
Weight	38 Pounds	Crated
	22 Pounds	Uncrated
Frequency Range	225-399.95/ 399.975^n	MHz
No. of Channels	One	Quantity
Tuning Increments	$50/25^n$	kHz
Type of Receiver	One	No. of Conversions
IF Frequency	20.6 MHz	1st IF Frequency

TABLE 3. UHF RECEIVERS (TYPICAL CHARACTERISTICS) (CONT'D)
(Sheet 2)

EQUIPMENT CHARACTERISTICS AN/GRR-24	DESCRIPTION	IDENTIFICATION
	N/A	2nd IF Frequency
Frequency Stability	$0.002/0.001^n$	Percentage (Long Term)
Type. Freq. Control	Quartz Crystal/ Synthesizer	Description
	CR75/1	Type
	HC-6/U	Holder Type
Local Osc. Crystal	61.4 to 94.8375 MHz	Frequency Range
	0.0005 ppm	Crystal Tol.
	225 to 312 MHz	Frequency Range
	$F_c = \frac{F_r + 20.6}{4}$	Frequency Calculation
	312.05 to 399.95	MHz
	$F_c = \frac{F_r - 20.6}{4}$	Frequency Calculation

TABLE 3. UHF RECEIVERS (TYPICAL CHARACTERISTICS) (CONT'D)
(Sheet 3)

EQUIPMENT CHARACTERISTIC AN/GRR-24	DESCRIPTION	IDENTIFICATION
Emission	A3E	Modulation Type
Receiver Output	Watts 0.1 0.1	Level Output 1 Output 2
	Ohms 600 600	Impedance Output 1 Output 2
Sensitivity	3 µV	at 10 dB (S+N)/N 30% Modulation of 1000 Hz Tone 0.1 Watts Output
Selectivity	± $36/20^n$ kHz ± $80/50^n$ kHz	6dB Bandwidth 80dB Skirt BW
Automatic Volume Control (AVC)	6 µV To 1.0V	Audio Output Constant within 3 dB for Signal Input Ranging
	30 dB	Muting Range
Squelch Circuit	3 µV	At Max RF Gain
	50 µV	At Min RF Gain
Audio Response	+1, -2 dB	Level, Variation (300-3000 Hz)

TABLE 3. UHF RECEIVERS (TYPICAL CHARACTERISTICS) (CONT'D)
(Sheet 4)

EQUIPMENT CHARACTERISTICS AN/GRR-24	DESCRIPTION	IDENTIFICATION
Harmonic Distortion	10%	At 30% Modulation
	20%	At 90% Modulation
Notes:	[n] Figures for 25 kHz Spacing	

TABLE 4. VHF TRANSMITTERS (TYPICAL CHARACTERISTICS)
(Sheet 1)

EQUIPMENT CHARACTERISTICS AN/GRT-21	DESCRIPTION	IDENTIFICATION
Equipment Supplied	VHF Transmitter, E/W (Optional)	Single Frequency Oscillator Synthesizer
Prime Power	105, 120, 210 & 240 ±10%	AC Volts
	Single	AC Phase
	47-420 Hertz 22-30 (Alternate)	AC Frequency DC Volts
	140 Watts 610 Watts	Power, Exciter PA
Dimensions	5-1/4 Inches 7-0 Inches	Height, Exciter PA
	17-3/4 Inches	Width, Exciter PA
	16-7/8 Inches 18-1/2 Inches	Depth, Exciter PA
Weight	50 Pounds 80 Pounds	Crated, Exciter PA
	43 Pounds 70 Pounds	Uncrated, Excite PA

TABLE 4. VHF TRANSMITTERS (TYPICAL CHARACTERISTICS) (CONT'D)
(Sheet 2)

EQUIPMENT CHARACTERISTICS AN/GRT-21	DESCRIPTION	IDENTIFICATION
Frequency Range	$116\text{-}149.95/149.975^{n}$	MHz
No. of Channels	One	Quantity
Tuning Increments	$50/25^{n}$ kHz	Steps
Transmitter Output	Watts Exc 10, PA 50	Power At 90% Mod.
	50 Ohms	Impedance, (Exciter)
Type of Freq. Control	Crystal Oscillator/ Synthesizer	Description
Crystal	CR-75/U or CR-18/U	Type
Crystal Holder	HC-27/U	Type
Crystal Freq. Range	$58.0\text{-}74.975/74.9875^{n}$	MHz
Crystal Frequency	1:2	Ratio to Output
Frequency Stability	$\pm 0.002\ \pm 0.0005^{nn}$	Percentage (Long Term)
Harmonic & Spurious Output	80 dB	Down from Carrier -15 to +10 dBm Input Level Range
Audio Input	150/600 Ohms	Input Impedence
Audio Response	+1, -2 dB Refer 1 kHz 300 Hz - 6 kHz <15%	Level Variation (300-3000 Hz) Percentage Distortion

TABLE 4. VHF TRANSMITTERS (TYPICAL CHARACTERISTICS) (CONT'D)
(Sheet 3)

EQUIPMENT CHARACTERISTICS AN/GRT-21	DESCRIPTION	IDENTIFICATION
Noise Level	>50 dB Below 90% - Modulation	Wave Analyzer 1 kHz Ref
Max VSWR	Exc. 3:1; PA 3:1	Ratio
Wide Band Data Input	+1, -2 dB	Level Variation (300 Hz-25 kHz)
Special Features	Description	In Case of High VSWR, Exciter is Switched to the Antenna
Capabilities & Limitations	Description	Exciter or PA Can Be Used Separately
Emission	A3E	Modulation Type
Notes:	n Figures for 25 kHz Spacing nn Figures for Oscillator Synthesizer	

TABLE-5. UHF TRANSMITTERS (TYPICAL CHARACTERISTICS)
(Sheet 1)

EQUIPMENT CHARACTERISTICS AN/GRT-22	DESCRIPTION	IDENTIFICATION
Equipment Supplied	UHF Transmitter, E/W (Optional)	Single Frequency Oscillator Synthesizer
Prime Power	105, 120, 210 & 240 ±10%	AC Volts
	Single	AC Phase
	47-420 Hertz 22-30 Volts (Alternate)	AC Frequency DC Volts
	140 Watts 610 Watts	Exciter PA
Dimensions	5-1/2 Inches 7 Inches	Height, Exciter PA
	17-3/4 Inches 17-3/4 Inches	Width, Exciter PA
	16-7/8 Inches 18-1/2 Inches	Depth, Exciter PA
Weight	43 Pounds 70	Uncrated, Exciter PA
Frequency Range	225-399.95/399.975^n	MHz
No. of Channels	One	Quantity
Tuning Increments	50/25^n kHz	Steps

TABLE 5. UHF TRANSMITTERS (TYPICAL CHARACTERISTICS) (CONT'D)
(Sheet 2)

EQUIPMENT CHARACTERISTICS AN/GRT-22	DESCRIPTION	IDENTIFICATION
Transmitter Output	Watts Exe. 10, PA 50	Power At 90% Mod.
	Exe. 50; PA 50	Impedence
Type of Freq. Control	Crystal Oscillator/ Synthesizer	Type
Crystal	CR-75/U or CR-18/U	Type
Crystal Holder	HC-27/U	Type
Crystal Freq. Range	58.25-9.9875/ 99.99575^{n}	MHz
Crystal Frequency	1:4	Ratio to Output
Frequency Stability	± 0.002, $\pm 0.0005^{nn}$	Percentage (Long Term)
Harmonic & Spurious Output	80dB	Down from Carrier -15 to +10 dBm Input Level Range
Audio Input	150 or 600 Ohms	Input Impedence
Audio Response	+1, -2 dB Refer 1 kHz (300-600 Hz)	Level Variation (300-3000 Hz)
	< 15%	Percentage Distortion
Emission	A3E	Modulation Type
Noise Level	$\geq$ 50 dB Below 90% Modulation	Wave Analyzer 1 kHz Ref

TABLE 5. UHF TRANSMITTERS (TYPICAL CHARACTERISTICS) (CONT'D)
(Sheet 3)

EQUIPMENT CHARACTERISTICS AN/GRT-22	DESCRIPTION	IDENTIFICATION
Max VSWR	Exc. 3:1; PA 3:1	Ratio
Wide Band Data Input	-2 to +1 dB	Level Variation (300 Hz - 25 kHz)
Special Features	Description	In Case of High VSWR, Exciter Is Switched to The Antenna
Capabilities & Limitations	Description	Exciter or PA Can Be Used Separately
Notes:	n Figures for 25 kHz Spacing nn Figures for Oscillator Synthesizer	

TABLE 6. NEW VHF RECEIVERS (TYPICAL CHARACTERISTICS)
(Sheet 1)

EQUIPMENT CHARACTERISTICS FA-10452	DESCRIPTION	IDENTIFICATION
Equipment Supplied NSN 5820-01-369-13551	VHF Receiver	Single Frequency Oscillator Synthesizer
Prime Power	120 ±10%	AC Volts
	Single	AC Phase
	57-63 Hertz 24V (+20%, -10%)	AC Frequency DC Volts
	8 Watts	Power
Dimensions	3 1/2 Inches	Height
	17 Inches (19 Inches Rack Mt.)	Width
	11-1/2 Inches	Depth
Weight	31 Pounds	Crated
	15 Pounds	Uncrated
Frequency Range	117.975 to 136.975	MHz
No. of Channels	one (set)	Quantity
Tuning Increments	25 kHz	Channel Spacing
Type of Receiver	Dual	Conversions
IF Frequency	45 MHz	1st IF Freq.
	455 kHz	2nd IF Freq.
Frequency Stability	±0.0005 (≤5 PPM)	Percentage (Long Term)

TABLE 6. NEW VHF RECEIVERS (TYPICAL CHARACTERISTICS) (CONT'D)
(Sheet 2)

EQUIPMENT CHARACTERISTICS FA-10452	DESCRIPTION	IDENTIFICATION
Oscillator, Source	16.8 MHz	Frequency Std
Emission	A3E	Modulation Type
Receiver Output Level	0.1 Watts 0.1 Watts	Output 1 Output 2
	Ohms 600 CT 600 CT	Impedance Output 1 Output 2
Sensitivity	≤3.0 μV	at 10 dB (Sinad) at 30% AM Modulation with a 1000 Hz Tone 0.1 Watts Output
Selectivity	±9 kHz	<6dB IF Bandwidth
	±25 kHz	>60dB Skirt BW
Automatic Volume Control (AVC)	3 μV to .5V Input Ranging	Audio Output Constant within 3 dB for Signal
Squelch Circuit	<3.0 μV >30 μV	At Max RF Gain At Min RF Gain
Audio Response	±2 dB	Level, Variation (300-3000 Hz)
Harmonic Distortion	<10%	At 50% AM Mod.

Notes:

TABLE 7. NEW UHF RECEIVERS (TYPICAL CHARACTERISTICS)
(Sheet 1)

EQUIPMENT CHARACTERISTICS FA-10453	DESCRIPTION	IDENTIFICATION
Equipment Supplied NSN 5820-01-369-13541	UHF Receiver,	Single Frequency Oscillator Synthesizer
Prime Power	120 ±10%	AC Volts
	Single	AC Phase
	57-63 Hertz 24V (+20%, -10%) (Alternate)	AC Frequency DC Volts
	8 Watts	Power
Dimensions	3-1/2 Inches	Height
	17 Inches (19 inch Rack Mt.)	Width
	11 1/2 Inches	Depth
Weight	31 Pounds	Crated
	15 Pounds	Uncrated
Frequency Range	225-399.975	MHz
No. of Channels	One (set)	Quantity
Tuning Increments	25 kHz	Channel Spacing
Type of Receiver	Dual	No. of Conversions
IF Frequency	45 MHz	1st IF Frequency
	455 kHz	2nd IF Frequency

TABLE 7. NEW UHF RECEIVERS (TYPICAL CHARACTERISTICS) (CONT'D)
(Sheet 2)

EQUIPMENT CHARACTERISTIC FA-10453	DESCRIPTION	IDENTIFICATION
Frequency Stability	±0.0005 (≤5 PPM)	Percentage (long Term)
Frequency Source	16.8 MHz	Frequency Std.
Emission	A3E	Modulation Type
Receiver Output Level	0.1 Watts 0.1 Watts	Output 1 Output 2
	Ohms 600 CT 600 CT	Impedance Output 1 Output 2
Sensitivity	≤3.0 μV	at 10 dB (Sinad) at 30% AM Modulation with a 1000 Hz Tone 0.1 Watts Output
Selectivity	±9 kHz ±25 kHz	<6dB IF Bandwidth >60dB Skirt BW
Automatic Volume Control (AVC)	3 μV To 0.5V	Audio Output Constant within 3 dB for Signal Input Rangeing
Squelch Circuit	<3 μV >30 μV	At Max RF Gain At Min RF Gain
Audio Response	±2 dB	Level, Variation (300-3000 Hz)
Harmonic Distortion	<10%	At 50% AM Mod.

Notes:

TABLE 8. NEW VHF TRANSMITTERS (TYPICAL CHARACTERISTICS)
(Sheet 1)

EQUIPMENT CHARACTERISTICS FA-10450	DESCRIPTION	IDENTIFICATION
Equipment Supplied NSN 5820-01-369-13521	VHF Transmitter,	Single Frequency Oscillator Synthesizer
Prime Power	120 ±10%	AC Volts
	Single	AC Phase
	57-63 Hertz	AC Frequency
	24V (+20%, -10%) (Alternate)	DC Volts
	115 Watts	Power, AC
Dimensions	5-1/4 Inches	Height
	17 Inches (19 Inches Rack Mt)	Width
	16-1/5 Inches	Depth
Weight	45 pounds	Crated
	29.4 pounds	Uncrated
Frequency Range	117.975 to 136.975	MHz
No. of Channels	One (set)	Quantity
Tuning Increments	25 kHz	Steps
Transmitter Output	10 Watts (carrier)	Power (Nominal)
	36 Watts PEP	at 90% Mod.
	50 Ohms (nominal)	Impedance
Frequency Source	16.8 MHz	Frequency Std.

TABLE 8. NEW VHF TRANSMITTERS (TYPICAL CHARACTERISTICS) (CONT'D)
(Sheet 2)

EQUIPMENT CHARACTERISTICS FA-10450	DESCRIPTION	IDENTIFICATION
Frequency Stability	±0.0005 (≤5 PPM)	Percentage (Long Term)
Harmonic Output Spurious Output	-70 dBc -80 dBc	Down from Carrier
Noise Power	≥164 dBc/Hz	Freq. ≥ ±4 MHz
Audio Line	600 Ohms Ct. Balanced	Input Impedence -25 to +10 dBm Range for 90% AM Modulation
Audio Frequency Response	±2 dB Ref. 1 kHz	Level Variation (300-3000 Hz)
Audio Distortion	<15%	Percentage at 90% AM Mod.
Carries AM Noise	≥40 dB	Below 90% AM Modulation
Mismatch Permitted	∞ VSWR	No Damage
Special Features	Description	In Case of High VSWR, Exciter Output Reduced
Capabilities & Limitations	Description	Exciter, not Compatible with GRT LPA Equip.
Emission	A3E	Modulation Type
Notes:		

TABLE-9. NEW UHF TRANSMITTERS (TYPICAL CHARACTERISTICS)
(Sheet 1)

EQUIPMENT CHARACTERISTICS FA-10451	DESCRIPTION	IDENTIFICATION
Equipment Supplied NSN 5820-01-369-13531	UHF Transmitter,	Single Frequency Oscillator Synthesizer
Prime Power	120 ±10%	AC Volts
	Single	AC Phase
	57-63 Hertz	AC Frequency
	24V (+20%, -10%) (Alternate)	DC Volts
	115 Watts	Power, AC
Dimensions	5-1/4 Inches	Height
	17 Inches (19 Inches Rack Mt)	Width
	16-1/5 Inches	Depth
Weight	30 Pounds	Uncrated
Frequency Range	225 to 399.975	MHz
No. of Channels	One (set)	Quantity
Tuning Increments	25 kHz	Steps
Transmitter Output	10 Watts (Carrier)	Power(Nominal)
	36 Watts PEP	at 90% AM Mod.
	50 Ohms (Nominal)	Impedence
Frequency Source	16.8 MHz	Frequency Std.

TABLE 9. NEW UHF TRANSMITTERS (TYPICAL CHARACTERISTICS) (CONT'D)
(Sheet 2)

EQUIPMENT CHARACTERISTICS FA-10451	DESCRIPTION	IDENTIFICATION
Frequency Stability	±0.0005 (≤5 PPM)	Percentage (Long Term)
Harmonic Output Spurious Output	-70 dBc -80 dBc	Down from Carrier
Noise Power	≥164 dBc/Hz	Freq. ≥ ±4 MHz
Audio Line	600 Ohms Ct. Balanced	Input Impedence -25 to +10 dBm Range for 90% AM Modulation
Audio Response	±2 dB Ref. 1 kHz	Level Variation 300 to 3000 Hz
Audio Distortion	<15%	Percentage at 90% AM Mod.
Emission	A3E	Modulation Type
Carrier AM Noise	≥40 dB	Below 90% AM Modulation
Permissible Mismatch	∞ VSWR	With No Damage
Special Features	Description	In Case of High VSWR, Exciter Output Reduced
Capabilities & Limitations	Description	Exciter, not Compatible with GRT LPA
Notes:		

TABLE 10. TACO ANTENNA (ELECTRICAL CHARACTERISTICS)

CHARACTERISTIC	D-2276/DPV35	D-2277/DPV37	D-2261A/DPV40([m]B)	Y102B-130V/YG118
Antenna type	VHF	UHF	VHF	VHF: Yagi
Freq Range (MHz)	118-136	225-400	118-136	118-136
Gain (dBi min)[n]	0	0	4 (approx)	10
Polarization	Vertical	Vertical	Vertical	Vertical
Elevation beamwidth	65 (centered on horizon)	65(centered on horizon)	40 (centered on horizon)	50 (centered on horizon)
Azimuthal beamwidth	±1.0 dB (azimuth)	±1.0 dB (azimuth)	±1.0 dB (azimuth)	Directional
VSWR (max)	2:1	2:1	2:1	2:1
Terminal: Type	"N"	"N"	"N"	"N"
Terminal: Impedance	50 ohms	50 ohms	50 ohms	50 ohms
DC Impedance	0 ohms	0 ohms	0 ohms	0 ohms
RF power rating	50 W	50 W	50 W ([m]200W)	150 W
Vert beam-center deviation	±10 degrees (from horizon)	±10 degrees (from horizon)	±10 degrees (from horizon)	±10 degrees (from horizon)

[n] Gain relative to an isotropic source.

TABLE 10. TACO ANTENNA (ELECTRICAL CHARACTERISTICS) (CONT'D)

CHARACTERISTIC	D-2273/DPV39	D-2772/DPV36	D-2274/DPV38
Antenna Type	UHF/ VHF	VHF/VHF	UHF/UHF
Freq Range (MHz)	225-400 118-136	118-136 118-136	225-400 225-400
Gain (dBi min)n	0	0	0
Polarization	Vertical	Vertical	Vertical
Elevation beamwidth	65 (centered on horizon)	65 (centered on horizon)	40 (centered on horizon)
Azimuthal beamwidth	±1.0 dB (azimuth)	±1.0 dB (azimuth)	±1.0 dB (azimuth)
VSWR (max)	2:1	2:1	2:1
Terminal: Type	"N"	"N"	"N"
Terminal: Impedance	50 ohms	50 ohms	50 ohms
DC Resistance	0 ohms	0 ohms	0 ohms
RF power rating	50 W	50 W	50 W
Vert beam-center deviation	±10 degrees (from horizon)	±10 degrees (from horizon)	±10 degrees (from horizon)

n Gain relative to an isotropic source.

TABLE 11. TACO ANTENNA (PHYSICAL CHARACTERISTICS)

CHARACTERISTIC	D-2276	D-2277	D-2261A	D-2273
Height	54.50 in. (138.43 cm)	32.25 in. (81.91 cm)	140.50 in. (356.87 cm)	84.25 in. (213.99 cm)
Weight	5.2 lbs (2.36 kg)	3.9 lbs (1.77 kg)	19 lbs (8.63 kg)	11.2 lbs (5.08 kg)
Mount (mast dia.)	1.25 in. (3.175 cm)	1.25 in. (3.175 cm)	1.25 in. (3.175 cm)	1.25 in. (3.175 cm)
	or 2.5 in. (6.35 cm)	or 2.5 in. (6.35 cm)	or 2.5 in. (6.35 cm)	or 2.5 in. (6.35 cm)
Windloading (operating)	85 knots with 1/2 in. (1.27 cm) radial ice	85 knots with 1/2 in. (1.27 cm) radial ice	85 knots with 1/2 in. (1.27 cm) radial ice	85 knots with 1/2 in. (1.27 cm) radial ice
Environmental (operating temperature)	-50^{o} C to $+70^{o}$ C	-50^{o} C to $+70^{o}$ C	-50^{o} C to $+70^{o}$ C	-50^{o} C to $+70^{o}$ C
Relative Humidity	5% to 100%	5% to 100%	5% to 100%	5% to 100%

TABLE 11. TACO ANTENNA (PHYSICAL CHARACTERISTICS) (CONT'D)

CHARACTERISTICS	D-2272	D-2274
Height	152.25 (386.71 cm)	84.25 (213.99 cm)
Weight	17.5 lbs (7.95 kg)	10.9 lbs (4.95 kg)
Mount (mass dia.)	1.25 in. (3.175 cm) or 2.5 in. (6.35 cm)	1.25 in. (3.175 cm) or 2.5 in. (6.35 cm)
Windloading (operating)	85 knots with 1/2 in. (1.27 cm) radial ice	85 knots with 1/2 in. (1.27 cm) radial ice
Environmental (operating temperature)	-50° C to +70° C	-50° C to +70° C
Relative Humidity	5% to 100%	5% to 100%

CHARACTERISTICS	Y102B-130V
Length	102.25 in. (259.72cm)
Longest Element	50.00 in. (127.00cm)
Weight	22 lbs (9.99 kg)
Mount (mast dia.)	1.25 in. (3.18 cm) or 2.5 in. (6.35cm)
Windloading (85 knots with 1/2 in. (1.27 cm) radial ice)	150 lbs (68.04 kg)

TABLE 12. ANTENNA PRODUCTS CO. ANTENNA
(PHYSICAL CHARACTERISTICS)

CHARACTERISTIC	DPV-35	DPV-36	DPV-37
Height	50.50 in. (128.27 cm)	140.125 in. (355.92 cm)	27.125 in. (68.9 cm)
Weight	8 lbs (3.6 kg)	20 lbs (9 kg)	5 lbs (2.25 kg)
Diameter	2.35 in. (5.97 cm)	2.35 in. (5.97 cm)	2.35 in. (5.97 cm)
Mount (mast dia.)	1.25 in. (3.175 cm)	2.5 in. (6.35 cm)	1.25 in. (3.175 cm)
	or 2.5 in. (6.35 cm)		or 2.5 in. (6.35 cm)
Grounding	Grounded thru mounting hardware	Grounded thru mounting hardware	Grounded thru mounting hardware
Windloading (operating)	85 knots with 1/2 in. (1.27 cm) radial ice	85 knots with 1/2 in. (1.27 cm) radial ice	85 knots with 1/2 in. (1.27 cm) radial ice
Environmental (operating temperature)	-50^{o} C to $+70^{o}$ C	-50^{o} C to $+70^{o}$ C	-50^{o} C to $+70^{o}$ C
Relative Humidity	0 to 100%	0 to 100%	0 to 100%
Rain	Up to 7 in. per hour	Up to 7 in. per hour	Up to 7 in. per hour
Service Life	10 years continuous and unattended	10 years continuous and unattended	10 years continuous and unattended

TABLE 12. ANTENNA PRODUCTS CO. ANTENNA (PHYSICAL CHARACTERISTICS) (CONT'D)

CHARACTERISTIC	DPV-38	DPV-39	DPV-40/B
Height	69.375 in. (176.21 cm)	86.75 in. (220.35 cm)	123.125 in. (312.74 cm)
Weight	15 lbs (5.97 kg)	15 lbs (5.97 kg)	25 lbs (5.97 kg)
Diameter	2.5 in. (6.35 cm)	2.5 in. (6.35 cm)	2.5 in. (6.35 cm)
Mount (mast dia.)	2.5 in. (6.35 cm)	2.5 in. (6.35 cm)	2.5 in. (6.35 cm)
Grounding	Grounded thru mounting hardware	Grounded thru mounting hardware	Grounded thru mounting hardware
Windloading (operating)	85 knots with 1/2 in. (1.27 cm) radial ice	85 knots with 1/2 in. (1.27 cm) radial ice	85 knots with 1/2 in. (1.27 cm) radial ice
Environmental (operating temperature)	-50° C to $+70^{\circ}$ C	-50° C to $+70^{\circ}$ C	-50° C to $+70^{\circ}$ C
Relative Humidity	0 to 100%	0 to 100%	0 to 100%
Rain	Up to 7 in. per hour	Up to 7 in. per hour	Up to 7 in. per hour
Service Life	10 years continuous and unattended	10 years continuous and unattended	10 years continuous and unattended

TABLE 13. TYPICAL RECEIVER MULTICOUPLER SIGNAL SENSITIVITIES

RECEIVER FREQUENCY/EQ	WITH SIG AT Rx INPUT		WITH SIG AT MIC INPUT	
	SENS(uV)	SQUELCH(uV)	SENS(uV)	SQUELCH(uV)
122.2 #1 (note 1)				
#2				
122.65 #1	1.3	3.8	1.0	3.0
#2	1.6	3.8	1.5	3.0
124.25 #1	1.5	4.0	1.2	3.0
#2	1.0	4.0	1.0	3.0
127.75 #1	1.1	4.0	1.1	3.0
#2	0.9	3.8	1.1	3.0
133.275#1	1.0	4.4	0.9	3.0
#2 (note 2)	0.9	1.6	1.8	3.0
134.625#1	2.0	3.6	1.5	3.0
#2	1.0	3.6	1.5	3.0
255.4 #1 (note 1)				
#2				
263.1 #1	1.0	3.0	1.5	3.0
#2	1.3	4.0	1.7	3.0
296.7 #1	1.4	3.4	1.2	3.0
#2	4.8	2.9	3.2	3.0
319.0 #1	1.5	2.9	1.5	3.0
#2	1.5	2.3	1.5	3.0
346.4 #1	2.3	2.6	2.0	3.0
#2	1.5	2.3	2.6	3.0
380.3 #1	1.6	3.6	1.6	3.0
#2	1.8	2.6	2.2	3.0

NOTES:
1. Data was not taken for this frequency.
2. A bandpass cavity was connected between the receiver and the multicoupler.

TABLE 14. TYPICAL TRANSMITTER COMBINER CAVITY POWER LOSS AND VSWR

TRANSMITTER FREQUENCY/EQ		W/50 OHM LOAD AT CAVITY OUT		W/ANTENNA AT CAVITY OUT		VSWR (ON ANT)	
		TX OUT (WATT)	CAV OUT (WATTS)	TX OUT (WATTS)	CAV OUT (WATTS)	TX OUT	CAV OUT
122.2	#1	10	6.9	10	7.1	1.15	1.47
	#2	10	6.5	10	6.2	1.38	1.29
122.65	#1	10	6.9	10	6.0	1.63	1.43
	#2	10	6.8	10	6.4	1.70	1.37
124.25	#1	10	7.1	10	7.2	1.48	1.46
	#2	10	6.4	10	6.0	1.46	1.37
127.75	#1	10	5.9	10	6.4	1.38	1.49
	#2	10	6.8	10	7.6	1.55	1.55
133.275	#1	10	6.3	10	6.4	1.28	1.43
	#2	10	6.5	10	6.1	1.65	1.57
134.625	#1	10	6.6	10	6.5	1.34	1.51
	#2	10	7.0	10	7.1	1.79	1.62
255.4	#1	10	6.5	10	6.6.	1.28	1.19
	#2	10	6.6	10	6.8	1.35	1.19
263.1	#1	10	6.8	10	6.8	1.15	1.18
	#2	10	7.3	10	7.3	1.15	1.13
296.7	#1	10	7.0	10	6.8	1.15	1.18
	#2	10	7.0	10	6.7	1.27	1.15
319.0	#1	10	6.2	10	6.2	1.15	1.20
	#2	10	6.6	10	6.7	1.23	1.35
346.4	#1	10	6.5	10	6.7	1.38	1.39
	#2	10	6.5	10	6.6	1.19	1.20
380.3	#1	10	6.2	10	6.2	1.45	1.20
	#2	10	6.8	10	7.0	1.43	1.35

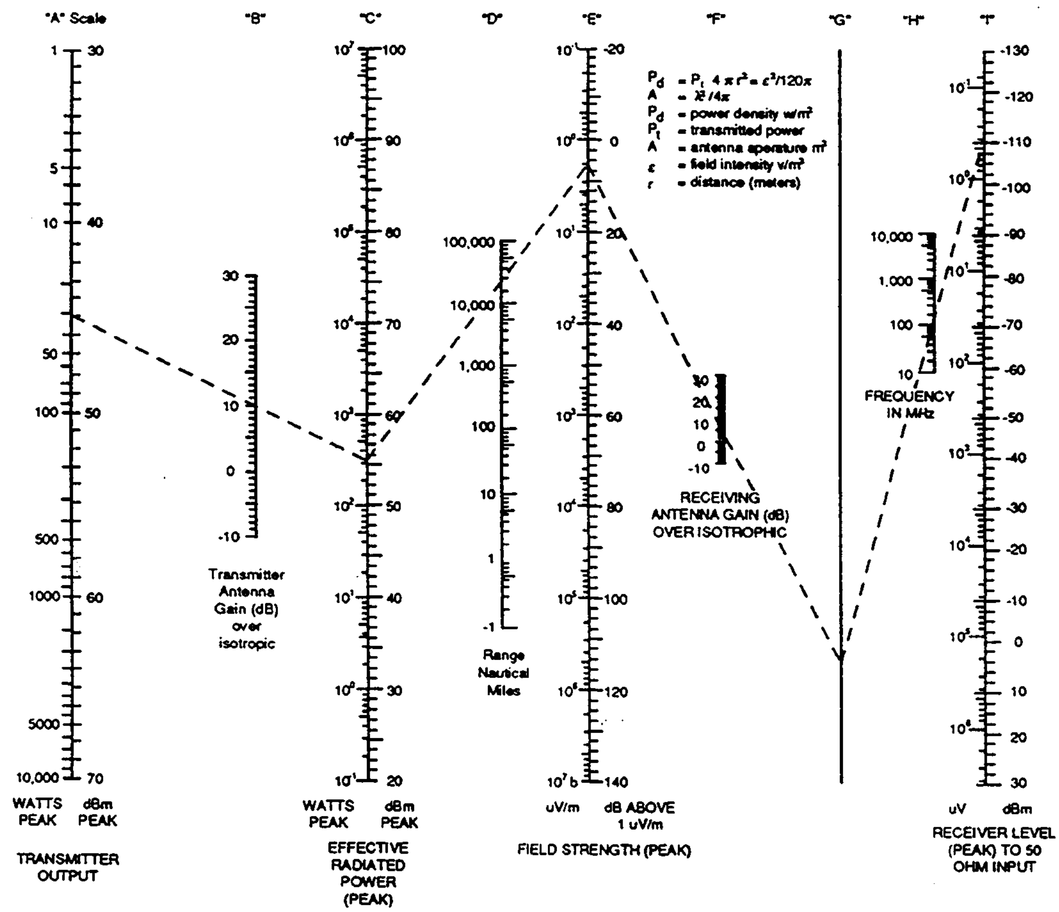
APPENDIX 4. NOMOGRAPHS

1. **PURPOSE**. This appendix contains typical nomographs as reference material used in the RCF design criteria review.

2. **CATEGORIES**. Figures 1 through 4, identify the A/G propagation relationships significant to radio communications equipment. Figures 5 and 6 along with table 1 identify relationships significant to communications audio modulation.

3.-5. **RESERVED**.

FIGURE 1. NOMOGRAPH FOR ELECTROMAGNETIC PROPAGATION IN FREE SPACE (100-100,000 MHz)



NOMOGRAPH FOR ELECTROMAGNETIC PROPAGATION IN FREE SPACE

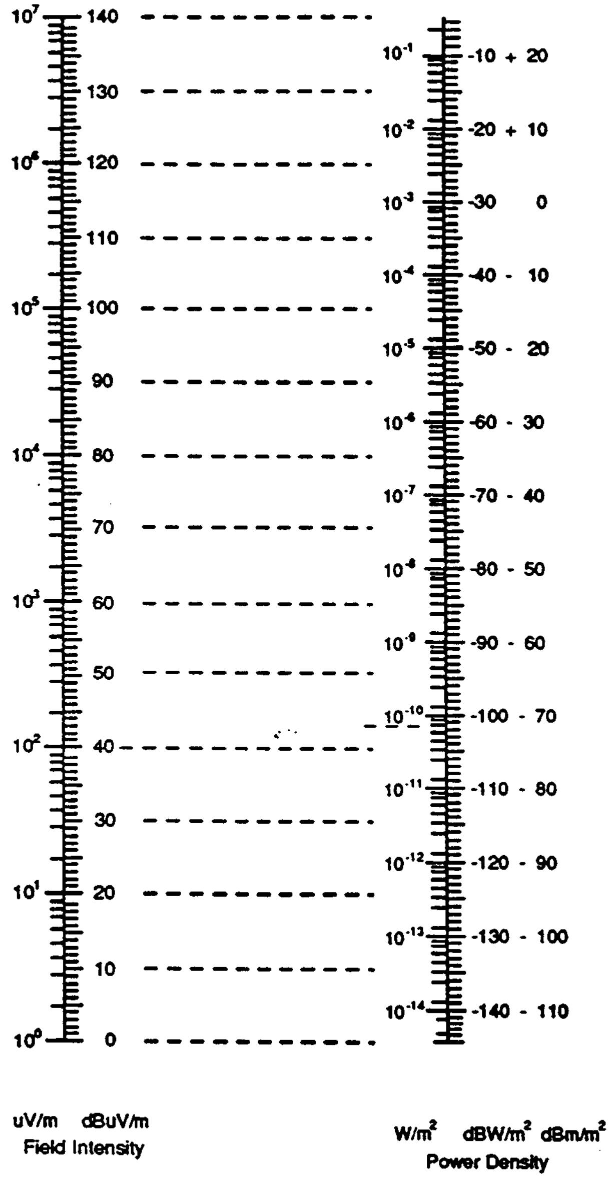
EXAMPLE: A 30 WATT TRANSMITTER USING A 10dB ANTENNA IS FOUND TO HAVE AN EFFECTIVE RADIATED POWER (ERP) OF 300 WATTS BY EXTENDING A LINE THROUGH SCALES "A";, "B" AND "C". THIS ERP PRODUCES A FIELD INTENSITY OF 2 MICRO VOLTS PER METER AT A RANGE OF 22,000 NAUTICAL MILES (LINE "CDE"). THE EFFECTS OF RECEIVING ANTENNA GAIN AND APERATURE ARE TAKEN INTO ACCOUNT WITH LINES "EFG" AND "GHI" INDICATING 0.75 MICRO VOLTS ACROSS A 50 ohm RECEIVER INPUT AT 130 MHz.

<u>COUPLING AND LINE LOSSES.</u> THESE LOSSES MAY BE FOR ON THE "A" AND "I" SCALES. A 60 WATT TRANSMITTER WITH 3 dB LOSS TO ANTENNA WOULD START AT THE SAME POINT AS THE EXAMPLE ABOVE. SIMILARLY, A 3dB LOSS BETWEEN RECEIVER AND ANTENNA WOULD BE ACCOUNTED FOR IN THE LOSS FREE EXAMPLE ABOVE AS AN ADDITIONAL STEP ON SCALE "I" (-110-3=-113 dBm, OR ABOUT 0.5 μV)

<u>ATTENTION IN EXCESS OF FREE SPACE CONDITIONS.</u> WHEN THE PROPAGATION LOSS IS GREATER THAN THAT OF FREE SPACE, THE FIELD INTENSITY (SCALE "E") SHOULD BE REDUCED ACCORDINGLY USING THE dB SCALE.

BASIC TRANSMISSION LOSS. THE PATH LOSS (AS DEFINED USING TWO LOSS-FREE ISOTROPIC ANTENNAS) IN THE EXAMPLE IS THE DIFFERENCE BETWEEN SCALES "A" AND "I" (45 + 110 dBm) PLUS ANTENNA GAINS AS SCALES "B" AND "F" (10+ 3dB) TOTALING 168dB

FIGURE 2. RADIO FIELD STRENGTH/POWER DENSITY CONVERSION CHART



Field Strength/Power Density Conversion Chart
(Ex: 100 uV/m (40 dB)= .266 W/m² (-105.7 dB W/m²...-75.7 dBm/m²)

FIGURE 3. RADIO GROUND-TO-AIR AND AIR-TO-AIR dB LOSS/NAUTICAL MILES CHART

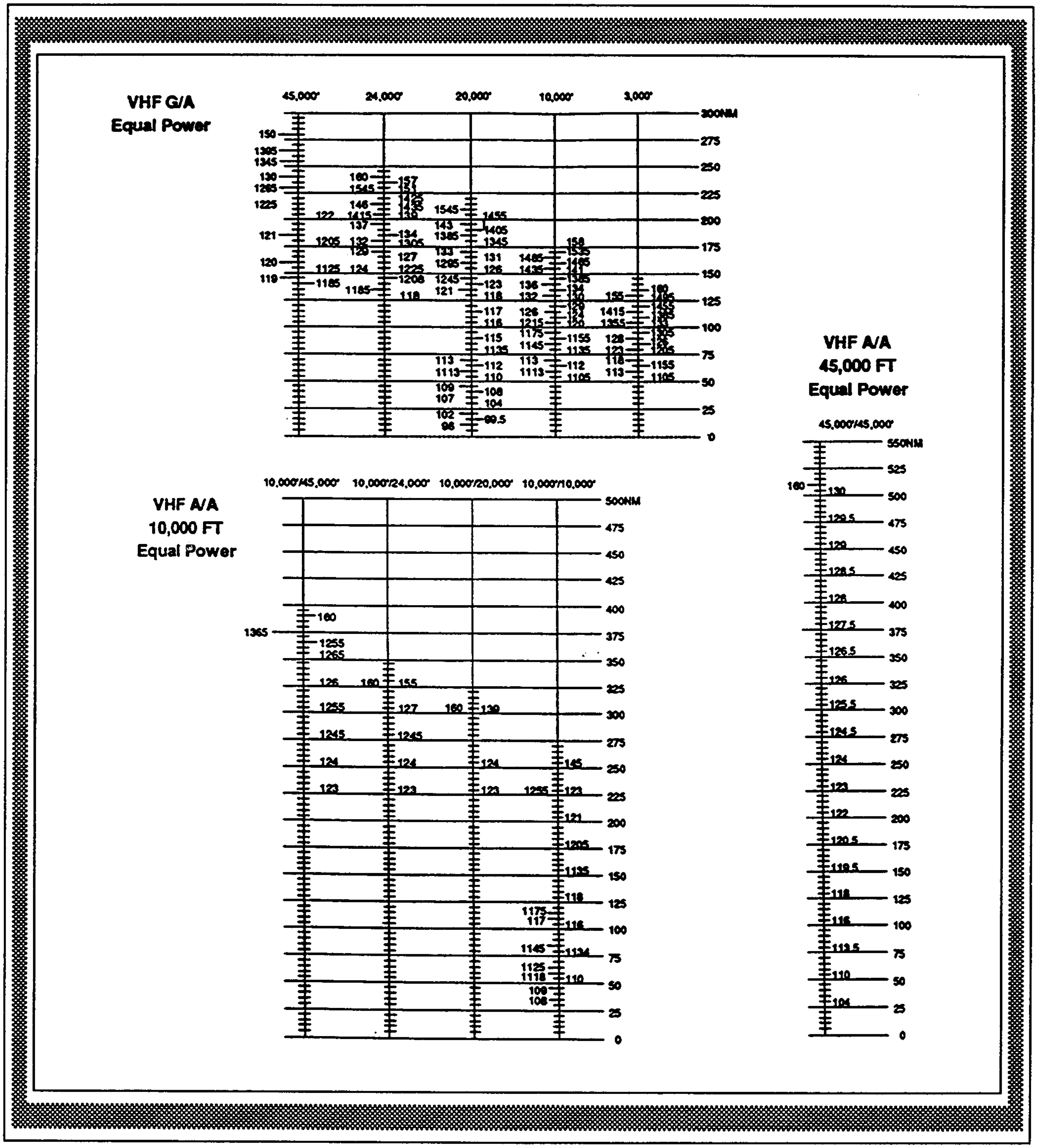
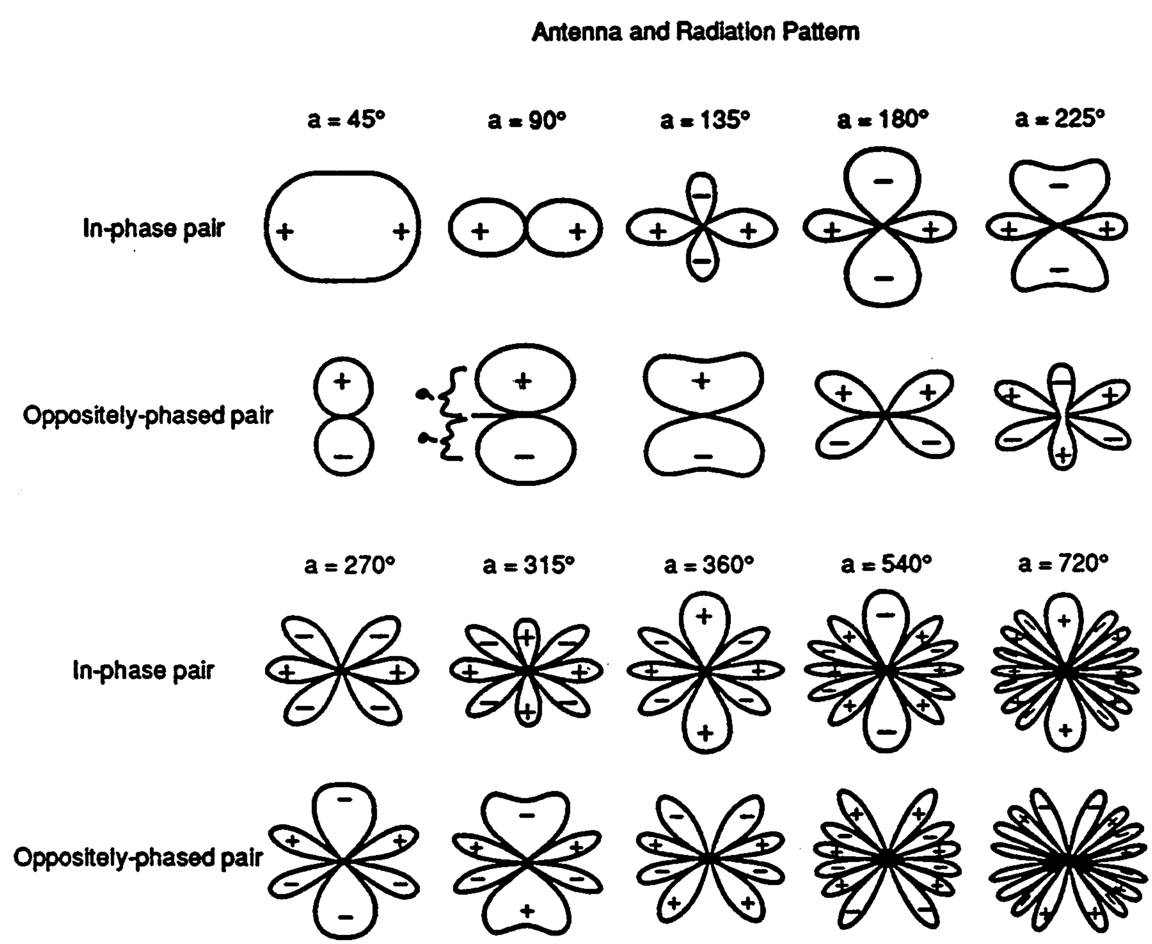


FIGURE 4. ANTENNA LOBING FOR PHASING SEPARATIONS OF 45 TO 720 DEGREES



Comparison of horizontal radiation patterns of antenna pairs of various spacings fed equal currents that are both in phase and oppositely phased

FIGURE 5. AUDIO dB-VU-dBm CHART

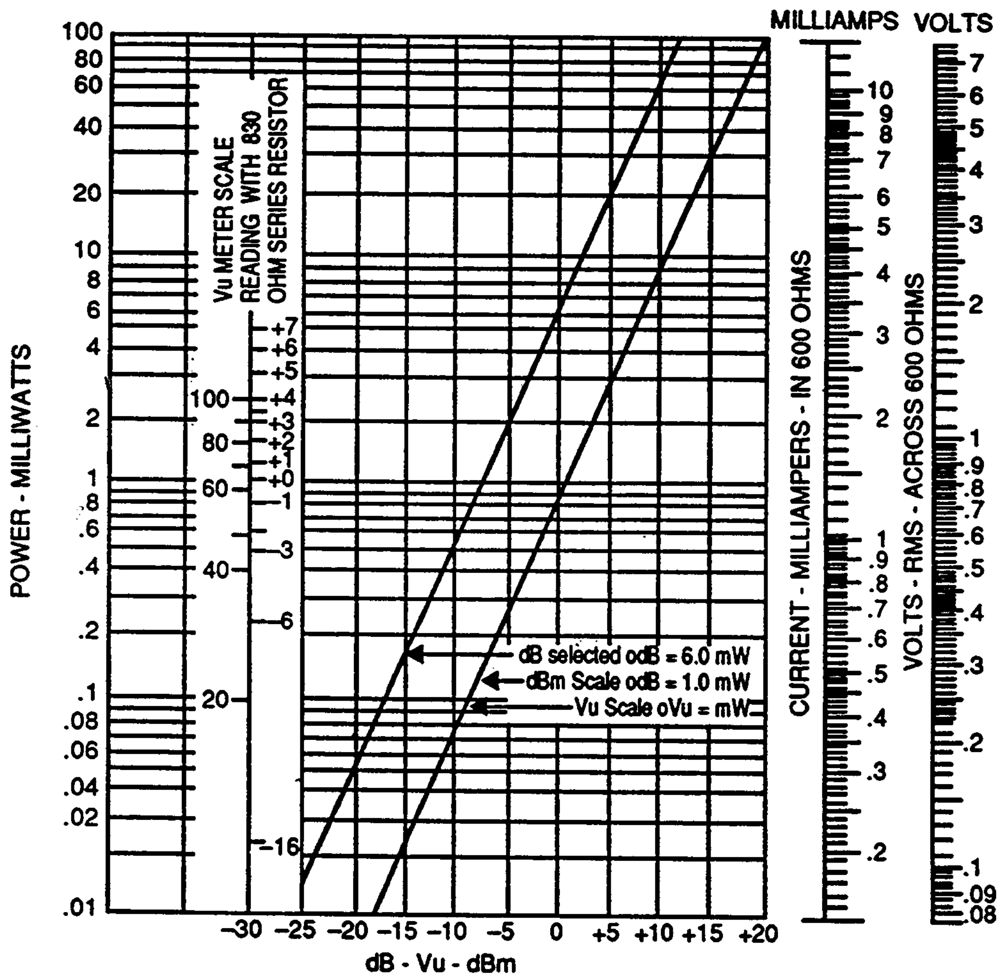


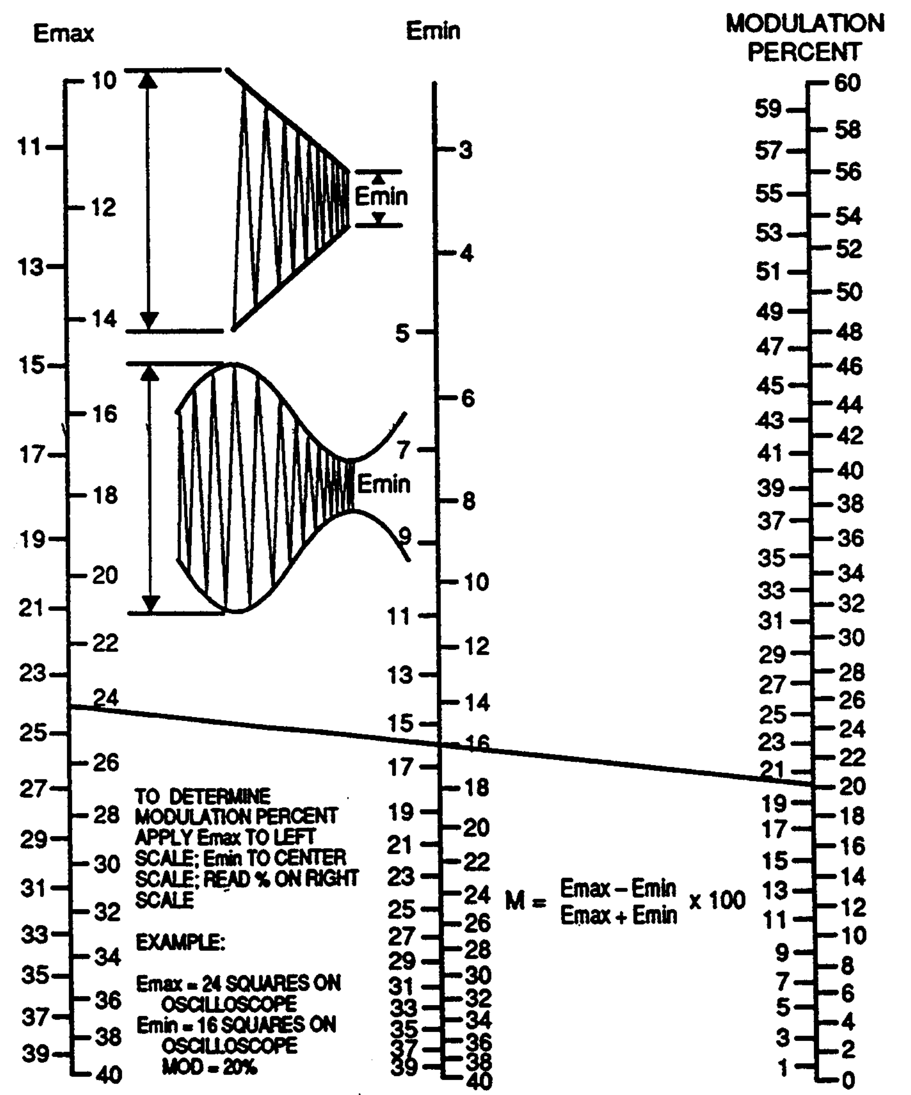
TABLE 15. AUDIO VOLTS/dBm CHART FOR 600 OHMS

DECIBELS ABOVE AND BELOW
A REFERENCE LEVEL OF 1mW INTO 600 OHMS

dB Down		*Level*	*dB Up*	
Volts	*Milliwatts*	*dBm*	*Volts*	*Milliwatts*
0.774 6	1.000	-0+	0.774 6	1.000
0.690 5	0.794 3	1	0.876 1	1.259
0.616 7	0.631 0	2	0.975 2	1.585
0.548 4	0.501 2	3	1.094	1.995
0.488 7	0.398 1	4	1.228	2.512
0.435 6	0.316 2	5	1.377	3.162
0.388 2	0.251 2	6	1.546	3.981
0.346 0	0.199 5	7	1.734	5.012
0.308 4	0.158 5	8	1.946	6.310
0.274 8	0.125 9	9	2.183	7.943
0.244 9	0.100 0	10	2.449	10.000
0.218 3	0.079 43	11	2.748	12.59
0.194 6	0.063 10	12	3.084	15.85
0.173 4	0.050 12	13	3.460	19.95
0.154 6	0.039 81	14	3.882	25.12
0.137 7	0.031 62	15	4.356	31.62
0.122 8	0.025 12	16	4.887	39.81
0.109 4	0.019 95	17	5.484	50.12
0.097 52	0.015 85	18	6.153	63.10
0.086 91	0.012 59	19	6.905	79.43
0.077 46	0.010 00	20	7.746	100.00
0.043 56	0.003 16	25	13.77	316.2
0.024 49	0.001 00	30	24.49	1.000W
0.013 77	0.000 316	35	43.56	3.162W
0.007 746	0.000 100	40	77.46	10.00W
0.004 356	3.16×10^{-5}	45	137.7	31.62W
0.002 449	1.00×10^{-5}	50	244.9	100W
0.001 377	3.16×10^{-6}	55	435.6	316.2W
0.000 774 6	1.00×10^{-6}	60	774.6	1 000W
0.000 453 6	3.16×10^{-7}	65	1 377	3 162W
0.000 244 9	1.00×10^{-7}	70	2 449	10 000W
0.000 137 7	3.16×10^{-8}	75	4 356	31 620W
0.000 077 46	1.00×10^{-8}	80	7 746	100 000W

NOTE: The power holds for any impedance, but the voltage holds only for 600 ohms.

FIGURE 6. TRANSMITTER MODULATION ANALYSIS



NOMOGRAPH FOR PERCENTAGE OF MODULATION – 0 TO 60 PERCENT

APPENDIX 5. RCF AIR-TO-GROUND FACILITY ANTENNA LOCATIONS

1. **GENERAL**. This appendix provides guidelines and requirements for locating and spacing the RCF antennas at the facility site. Interferences affecting VHF/UHF A/G communications are briefly discussed. Section 1 of this appendix describes the effect of each type of interference on the A/G communications system. The section also describes some tradeoffs that can be applied to achieve desired communications results even though physical restrictions prevent the use of ideal antenna arrangements. Section 1 also describes the relationship between receiver desensitization and off-frequency interference, transmitter intermodulation product interference, receiver spurious response, field propagation and lobing, and antenna spacing and frequency separation. Section 2 provides typical evaluation procedures for use as aids to examine interference problems and their solutions in greater depth.

SECTION 1. RCF AIR-TO-GROUND FACILITY ANTENNA REQUIREMENTS

2. **GENERAL**. The horizontal/vertical antenna radiation patterns, receiver desensitization, and available receiver input level are interrelated and collectively contribute to the phenomenon of dropout of the receiver radio signal.

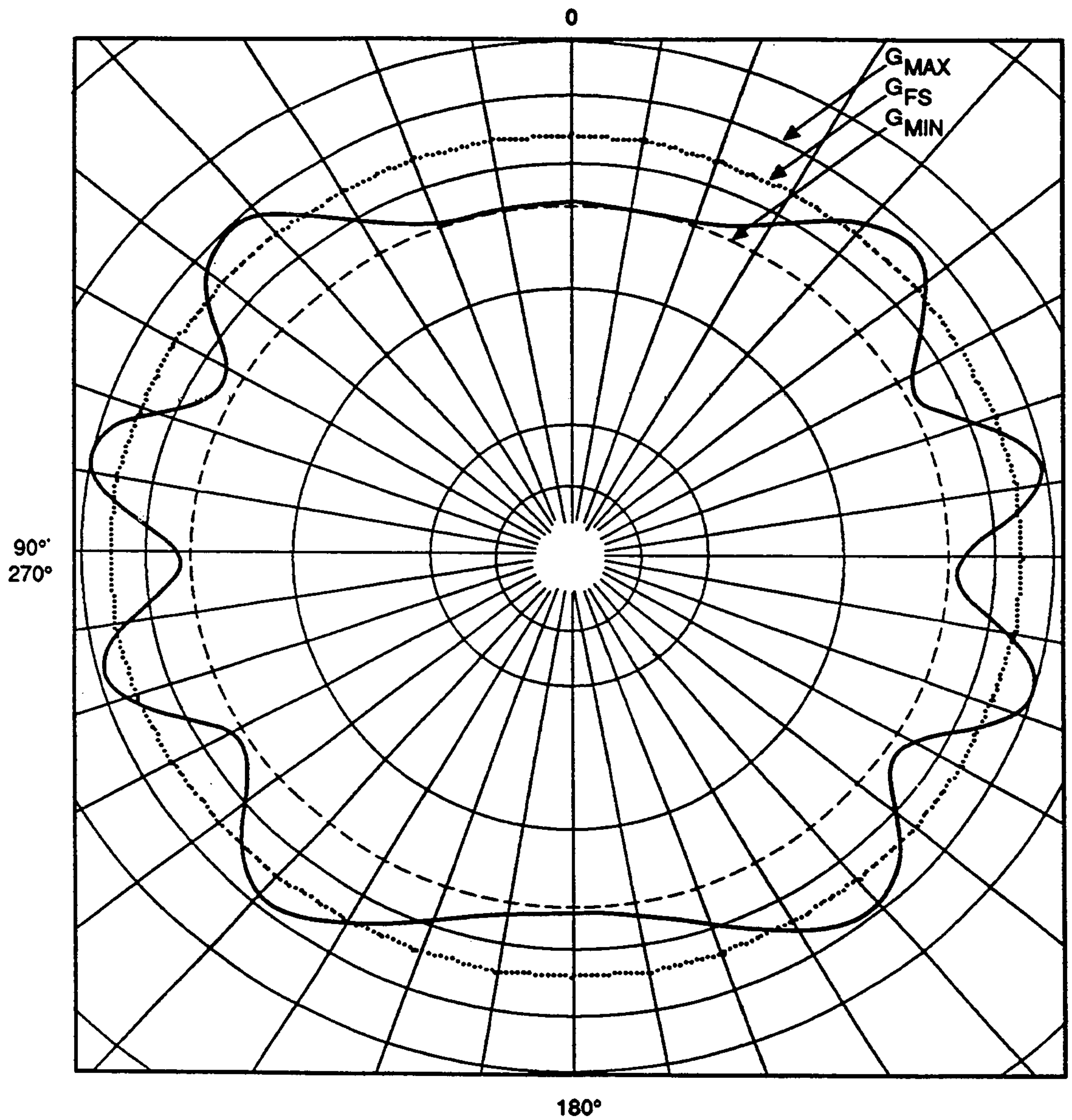
3. **ANTENNA PATTERN DISTORTION**. When a radiating antenna is located near another antenna, or conducting objects such as a lightning rod, currents from the radiating antenna are induced in the second antenna and reradiated. The sum, or difference in these two propagated fields, results in a change in radiated power in any given direction. This causes a variation of far-field coverage, or in worst case, signal dropout. Using 8 feet or more spacing between antenna-to-antenna or lightning rod (air terminal) minimizes the effect.

a. **Pattern Distortion**. The phase difference between the radiation from two antennas, active or parasitic, has a resultant far-field or Fraunhofer pattern that is characterized by disturbances in gain with respect to the ideal omnidirectional pattern of constant gain. This phenomenon is termed pattern distortion. The measure of pattern distortion is defined as the difference between the free-space omnidirectional gain of an antenna when other antennas are present. Only the gain in the horizontal plane is considered. See Figure 7, Antenna Pattern Distortion in the Horizontal Plane. The distortion parameter Lp_d is defined by:

$$Lp_d = G_{fs} - G_{min}$$

where: G_{fs} = free-space gain in dBi 38 + 20 LOG (FxD)
G_{min} = minimum gain of the horizontal pattern
F = Frequency in MHz

FIGURE 7. ANTENNA PATTERN DISTORTION IN THE HORIZONTAL PLANE



D = Distance in nautical miles or decimal portion of a nautical mile

b. **Antenna Pattern Distortion Parameter**. The antenna pattern distortion parameter has been developed from statistical analysis of available data on antenna pattern distortion and is used to analyze various closely spaced antenna configurations. In order to reduce pattern distortion to acceptable limits, it may be necessary to relocate and/or rearrange antennas at a site to achieve greater physical separation. In analyzing parallel and/or elevated antenna configurations, an additional factor comes into play; it is called antenna aperture correction. This factor is applied to the basic pattern distortion plane. The overall effect of the antenna aperture correction factor is to reduce the degree of the overall effect of pattern distortion. Further discussion of pattern distortion and antenna aperture correction is contained in section 2 of this appendix.

c. **Lobing and Curvature Effect**. Vertical lobing and earth curvature are the major problems in trying to provide -87 dBm throughout the Air Traffic required service volume. See Appendix 6, Vertacle Lobing for detailed derivation.

(1) Low Angle Vertical lobing equation = dB = 20 Log $[2I \sin (a^{o} \sin \theta)]$

set I = 0.5 for simplicity

a^{o} = Height to feed point of the antenna above ground in electrical degrees

θ = Vertical angle above the horizon

AH = Antenna feed point above ground in feet

AC = 300 x 3.28 / Frequency in MHz

a^{o} = (AH x 360)/AC

(2) Radio Earth Equations:

Radio antenna line-of-sight N miles = $1.225 \times [(H_1)^{1/2} + (H_2)^{1/2}]$

H_1 = Ground antenna height in feet above site elevation

H_2 = Aircraft height in feet above site elevation

(3) Radio Earth Curvature = H feet
$H_{ft} = D^2 \div 2$

D = statute miles between the site and aircraft -
$[1.225 \times (H_1)^{1/2}] \times 1.516$
Nautical Miles x 1.1516 = Statute Miles

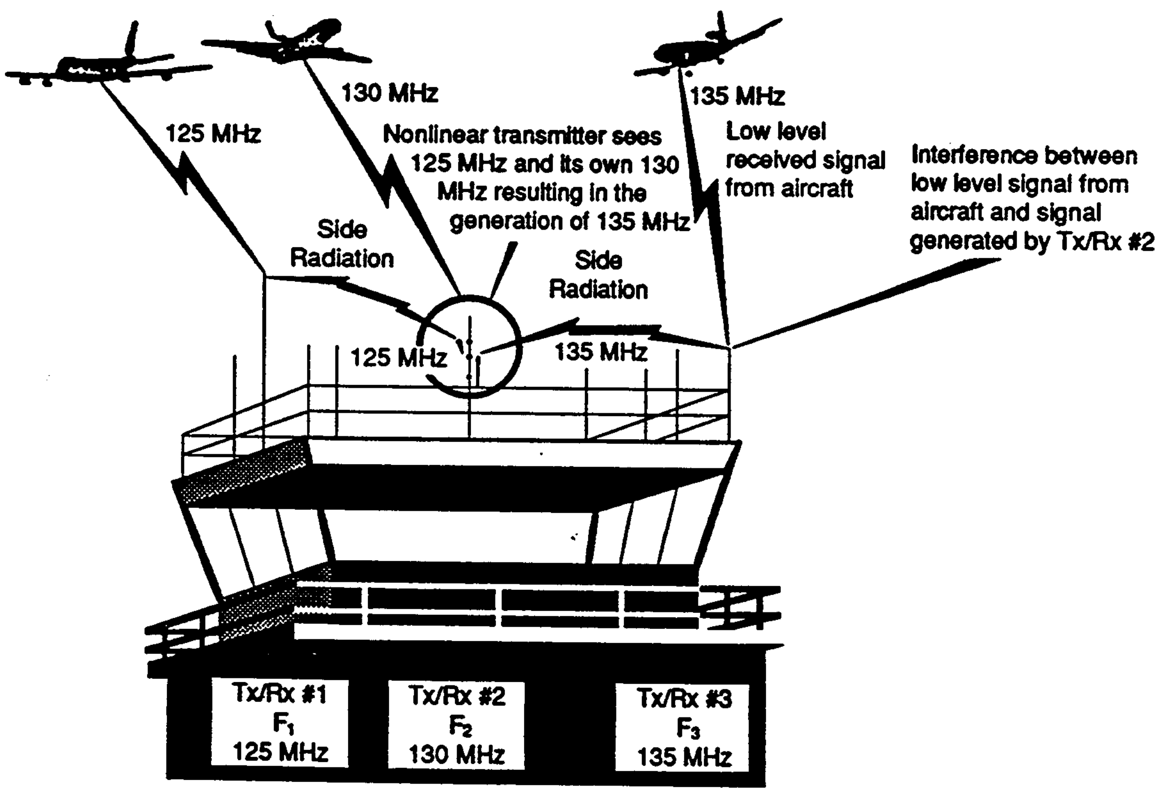
4. **RECEIVER DESENSITIZATION**. Receiver desensitization is one of the more serious interference problems associated with the operation of radio transmitters and receivers close to each other. Desensitization can be caused by any transmitter operating on a frequency other than the desired signal frequency. The signal causing the desensitization penetrates the front end of the affected receiver, alters the controlling bias voltages, and results in reduced receiver sensitivity. Keep 120 feet of space between transmitter and receiver antennas to minimize effects. Refer to paragraph 3, figure 9, figure 10, and appendix 8 for more information on receiver desensitization.

5. **TRANSMITTER INTERMODULATION PRODUCT INTERFERENCE**. In general, the output amplifier is the nonlinear component in which most transmitter intermods are generated. However, any nonlinear device can be a mixing agent for intermodulation products. These include such things as loose or corroded joints between two conductors, obstruction light filaments, lightning arrester blocks on telephone lines, and even the front end of the receiver itself.

a. **Transmitter Final Amplifier Generated Intermodulation**. Intermodulation interference signals generated in the final amplifier of a transmitter usually involve one or more offending signals external to the transmitter and travel backward along the output coaxial cable from the transmit antenna. The signals reach the final amplifier and combine with each of the transmitter's signals. The resultant interference signal then travels back on the output cable to the antenna to be radiated.

b. **Typical Transmitter Intermodulation**. Figure 8, Typical Transmitter Intermodulation Situation, depicts transmitter intermodulation as experienced by the FAA at some locations. In figure 8, the fundamental frequency (125 MHz) of transmitter number 1 enters transmitter number 2 through its antenna system and mixes with the second harmonic of the fundamental transmitter number 2 (130 MHz) to form a third order product (2F2 - F1). The resulting intermodulation product (135 MHz) appears at receiver number 3 on the desired signal frequency. The basic tradeoff factors for reducing this form of interference are spacing between transmit antennas, spacing between

FIGURE 8. TYPICAL TRANSMITTER INTERMODULATION SITUATION



transmit and receive antennas, and the use of isolation devices such as cavities and/or ferrite isolators.

c. **Frequency Management**. The best way to minimize transmitter IM product interference is through frequency management. However, as the requirement for collocated communications channels increases, the possibility of finding compatible frequency combinations decreases. When compatible frequencies cannot be found and large antenna separations cannot be implemented, bandpass cavity filters, ferrite isolators, cavity notch filters and transmitter combiners may be required between each transmitter and its antenna to reduce IM to -104 dBm or less.

6. **RECEIVER SPURIOUS RESPONSE**. When receivers have insufficient front-end selectivity between the antenna input and the first mixer, interference can be caused by adjacent transmitters, or nearby VHF frequency modulated broadcast transmitters.

a. **Adjacent Transmitter Interference**. If the output frequency of the transmitter penetrates the front-end of the receiver and combines with the local oscillator, spurious signals may be produced that fall within the passband of the receiver. If the interference is weak, it can be heard only when a desired signal breaks the preset squelch level.

b. **VHF Frequency Modulation Broadcast Transmitter Interference**. Interference can be caused by nearby frequency modulation broadcast transmitters operating on frequencies that duplicate local oscillator fundamental frequencies. A 5,000-watt transmitter located approximately one mile away or less can penetrate some receiver front-ends at broadcast frequency and mix with the receiver local oscillator. A spurious signal is produced for every multiple of the broadcast station frequency, both above and below the oscillator frequency.

c. **Elimination of Receiver Spurious Response Interference**. Receiver spurious response interference from adjacent communications transmitters can be minimized by following the same procedures used for receiver desensitization. Interference from a broadcast station can be eliminated by locating A/G communications receivers several miles from any broadcast station. Alternatively, bandpass or notch cavity filter and crystal filter devices can be used. Note that aircraft receivers are susceptible to RFI and front-end overload from commercial broadcast emission.

7. **INTERMODULATION SPURIOUS RESPONSE**. One of the most prevalent causes of interference in a receiver is intermodulation spurious response. This occurs when two or more strong off-channel signals generate intermodulation products. If one of these products coincides

with the operating frequency of the receiver, interference results. The intermodulation process takes place in the RF amplifier of a receiver when it operates in a nonlinear mode, or in the first mixer, which, must have nonlinear characteristics in order to perform as a mixer.

a. Receiver Selectivity. FAA receivers should have sufficient selectivity to operate without interference under the following conditions: transmitters on VHF frequencies equal to or greater than ± 500 kHz and for UHF frequencies equal to or greater than 1 MHz, from the receiver frequency. The selectivity for VHF AM receivers should be approximately ± 9 kHz at 6 dB and ± 18 kHz at 60 dB. Front end selectivity should offer approximately 100 dB rejection to frequencies ± 500 kHz/VHF, ± 1 MHz and greater.

b. Radio Frequency Interference Product. These products should be eliminated by frequency assignment action when they involve harmonics, image frequency, or fundamental frequency mixes that have products on local frequencies.

8. FAR-FIELD PROPAGATION AND LOBING.

a. Propagation (Space) Loss. Far-field propagation loss can be determined from VHF and UHF propagation charts in Order 6050.32, Spectrum Management and Procedures Manual and ESSA Technical Report ERL-111-ITS-79. Space attenuation data from these charts can be used to determine signal margins available in various A/G communications facilities and an aircraft at the outer limit of each service volume is used. Note that flight inspection requirement is -93 dBm or 5 uV at the aircraft receiver input throughout the service volume for both VHF and UHF.

b. Preliminary Facility Planning Phase. Section 2 of this appendix contains graphs for checking antenna pattern distortion, receiver desensitization, and transmitter intermodulation during the preliminary facility planning phase. In developing the graphs, a nominal gain/loss factor of 0.0 dB was assumed for an antenna and coaxial feeder system.

c. Vertical Lobing. Far-field lobing of the vertical antenna pattern affects transmission coverage. Vertical lobing is a function of aircraft altitude, facility antenna height, frequency and ground conductivity. Antenna heights at a facility must be limited to achieve gapless radio transmission (coverage in the deepest vertical null) at the limits of the service volume. Appendix 6, discusses vertical lobing more thoroughly. The discussion recommends antenna heights for terminal and en route service volumes.

9.-14. RESERVED.

SECTION 2. TECHNIQUES FOR EVALUATING ANTENNA CONFIGURATIONS AT A/G FACILITIES

15. **GENERAL**. The major portion of this section is devoted to special techniques for evaluating antenna pattern distortion (lobing), receiver desensitization, and transmitter intermodulation interference. These three factors have the greatest influence on A/G communications at any facility.

a. **Receiver Interference Factors**. To cope with receiver interference factors, special curves have been developed for this RCF Installation Handbook. These curves will enable an engineer to evaluate pattern distortion effects between (1) antennas mounted in the same plane or staggered, (2) antennas and air terminals; (3) receiver desensitization for various transmitter and receiver antenna separations; (4) space separations between transmit and receive antennas; and (5) transmitter intermodulation interference relative to squelch level, service volume, frequency separation, and antenna spacing.

b. **Evaluation Techniques**. The techniques presented permit any antenna configuration associated with an A/G communications system at any FAA facility to be evaluated relative to its intended service. The techniques provide information on system performance in terms of the three main factors which can be traded off to develop an optimum antenna configuration. Basic antenna configurations can be evaluated to identify areas needing improvement; alternate configurations can be evaluated to determine the degree of improvement the areas would provide.

c. **Qualitative Judgments**. In evaluating results from an analysis, the operational reliability required at any given facility, relative to the current and potential activity level and type of service, should be considered. These factors could be quantified by means of an activity analysis, but this is beyond the scope of this order. Instead, qualitative judgments can be made as to the need to arrange antennas to avoid undesired effects identified by the techniques presented herein.

16. **ESTIMATING ANTENNA PATTERN DISTORTION**. Antenna pattern distortion can be estimated by considering the effect of each antenna or conducting element (for example, an air terminal) in each group of antennas at a facility.

a. **Antenna Spacing to Avoid Antenna Pattern Distortion**. Wherever practical, a minimum of 8 feet spacing between the antenna and the supporting tower, air terminals, or other towers should be maintained to avoid antenna distortion caused by scattering from the supporting tower, air terminals, and other antennas.

b. **Multiple Antenna Radiation Pattern Interreaction**. A single vertical distortion caused by scattering from the supporting tower, air terminals, and radiators located in an area clear of other antennas and vertical conducting objects is considered to have an omnidirectional or circular radiation pattern in the horizontal plane. When a second antenna is placed nearby, the radiation pattern of the first antenna exhibits dips and peaks which vary above and below the nominal value of the original circular pattern. The amplitude of the dips varies with frequency and antenna aperture in addition to distortion.

17. **RECEIVER DESENSITIZATION CALCULATIONS**. Receiver desensitization is calculated as a function of distance between transmitting and receiving antennas and of frequency separation between desired and interfering signals. The distance between transmit and receive antennas which prevents desensitization varies with the output power of the interfering transmitter and the off-frequency front-end attenuation characteristics of the receiver.

a. **Receiver Filters**. Bandpass or notch cavity filters that increase the off-frequency attenuation capability of the receiver to decrease receiver desensitization are recommended where close spacing of transmit and receive antennas cannot be avoided. Receiver desensitization can also be decreased by using equipment similar to feed forward phase cancellation devices.

b. **Transmit-to-Receive Antenna Spacing**. Figures 9 and 10, Receiver Desensitization diagrams the distances, in feet, between transmit and receive antennas which are required to prevent VHF/UHF receiver desensitization for various frequency differences between desired and undesired signals. These curves were developed by subtracting the receiver's specified front-end attenuation from the total attenuation required to reduce a transmitted power level of 40 dBm (10 Watt) or 47 dBm (50 Watt) to a reference power level of -97.5 dBm (receiver squelch level). The required remaining attenuation was then converted from space loss (in dB) to distance (in feet). Transmitter to receiver antenna spacings for stated frequency separations that appear above these curves are considered to be free from receiver desensitization effects. The recommended spacing is 120 feet.

18. **INTERMODULATION PRODUCT INTERFERENCE CALCULATIONS**. (See Appendix H for detailed derivation). Transmitter IM product interference occurs, at a communications facility, when two or more assigned frequencies produce intermodulation products on the desired frequency of one or more active receive channels. Frequency management normally avoids these frequency combinations whenever possible. However, there is a finite limit on the number of available channel frequencies for any specific communications service in any FAA region. Therefore, transmitter IM product frequency combinations cannot always be

FIGURE 9. VHF RECEIVER DESENSITIZATION

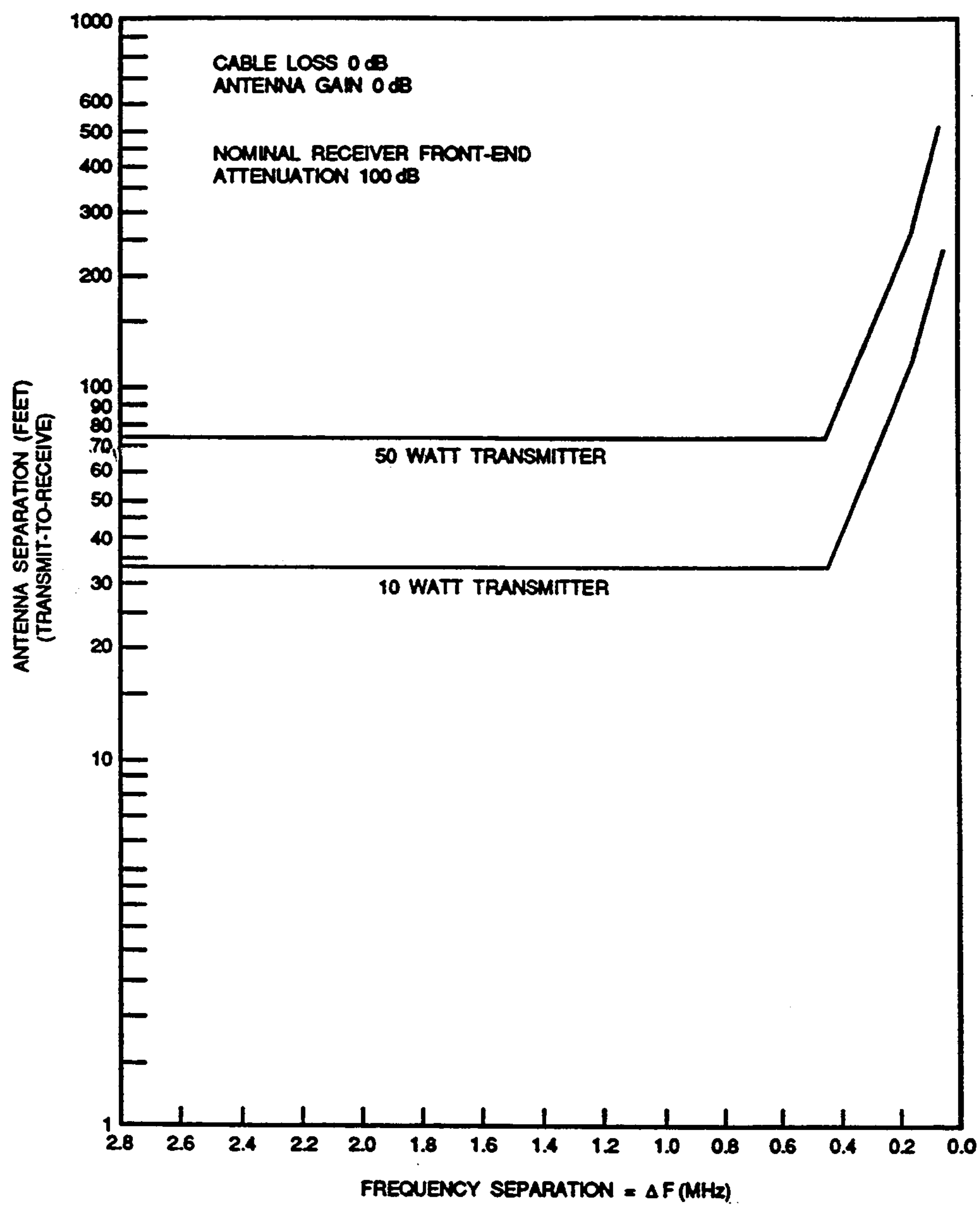
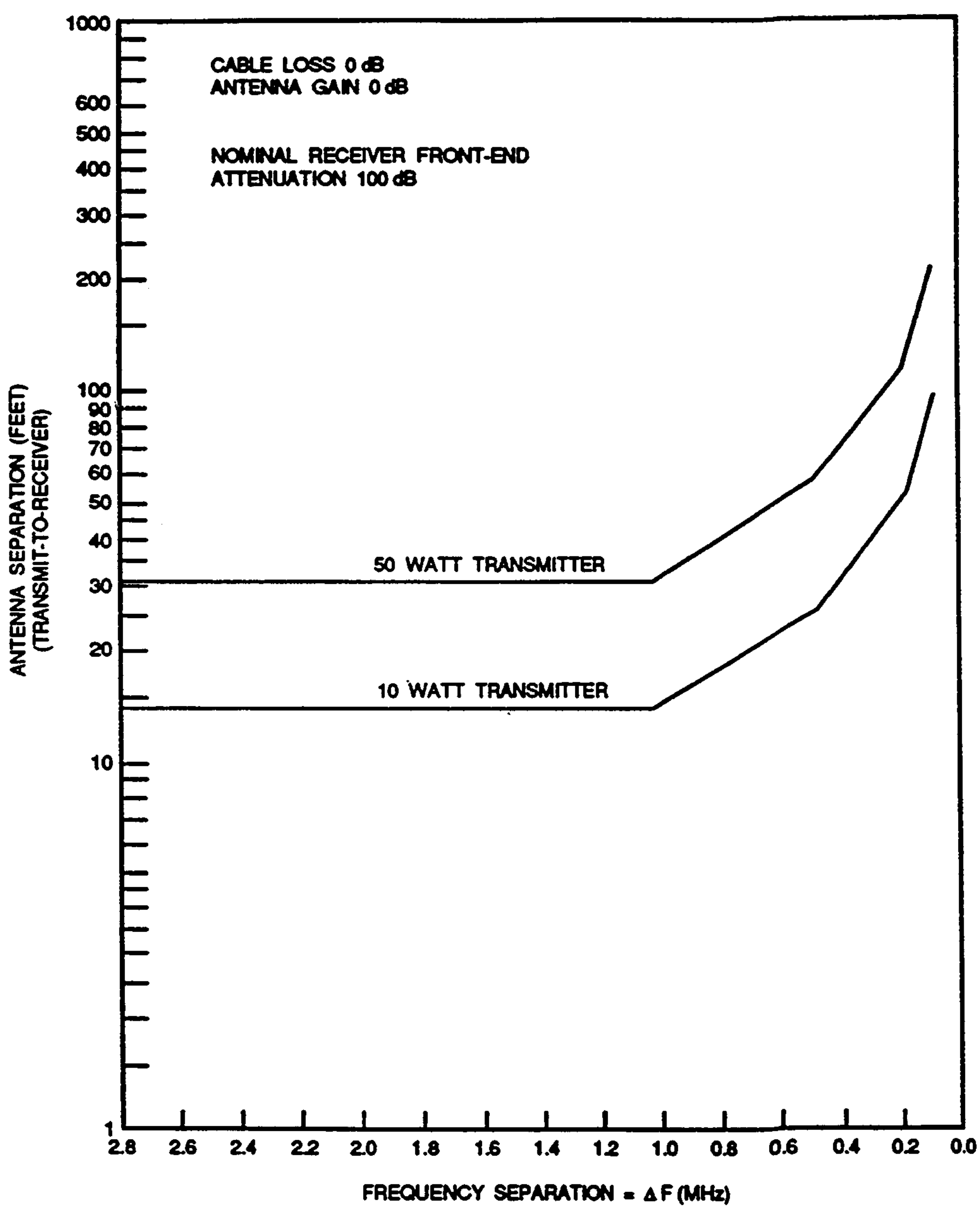


FIGURE 10. UHF RECEIVER DESENSITIZATION



circumvented. When this form of interference is inevitable, it can usually be reduced to an acceptable level by proper spatial separations between transmit antennas, between transmit and receive antennas, and through the proper use of tuned cavity filters and ferrite isolators.

a. **Tuned Cavity Filters and Ferrite Isolators**. Tuned cavity filters (cavity bandpass, notch or cavity combiner) and ferrite isolators may be used in the transmitter output to reduce the interference. Broad band ferrite isolators are effective regardless of the frequency separation between offending transmitters, whereas tuned cavity filters may require a frequency separation in excess of 1 MHz in order to be effective without causing excessive insertion loss. When space is limited, various combinations of antenna spacing and ferrite isolators can be combined to eliminate or reduce transmitter IM product interference to an acceptable level. Figure graphs herein designed to assist in planning for the elimination or reduction of IM product interference, were previously developed using 10 watt and 50 watt VHF and UHF transmitters.

b. **Reducing Intermodulation Product Interference**. Figure 11 through figure 14, provide graphic curves for 10 watt VHF and 10 watt UHF transmitters with and without tuned finals. The third order intermodulation product generated in an untuned transmitter will be approximately 22 dB below the lowest transmitter carrier level presented at the final RF amplifier. With tuned finals, there is an additional attenuation to external transmitter emissions that varies with frequency separation as follows: approximately 24 dB (0.5 MHz frequency separation) to 70 dB (5.0 MHz frequency separation). Therefore, the curves are presented according to the amount of interference reduction acceptable for the service volume signal requirements of terminal and en route facilities.

c. **Antenna Spacing Calculations Without Ferrite Isolators**. In figures 11 and 12, the lines show required spacing for antennas with and without the use of ferrite isolators. The graphic curves (-111.5 dBm) provide 14 dB desired to undesired signal ratio for terminal and en route facilities. Figures 13 and 14 present the same information for UHF transmitters.

d. **Antenna Spacing Trade Offs**. Figures 15 and 16 were developed for use with 50 watt VHF and UHF cavity tuned LPAs. The graphic curves in those figures show antenna spacings required to reduce transmitter IM interference to 14 dB below the squelch threshold level (-97.5 dBm) to -111.5 dBm with various frequency separations. These two figures make it possible for a field engineer, when analyzing antenna configurations, to perform trade offs in spacing to reduce IM interference. For example,

FIGURE 11. ANTENNA SPACING TO AVOID INTERMODULATION INTERFERENCE (VHF TX - UNTUNED FINAL)

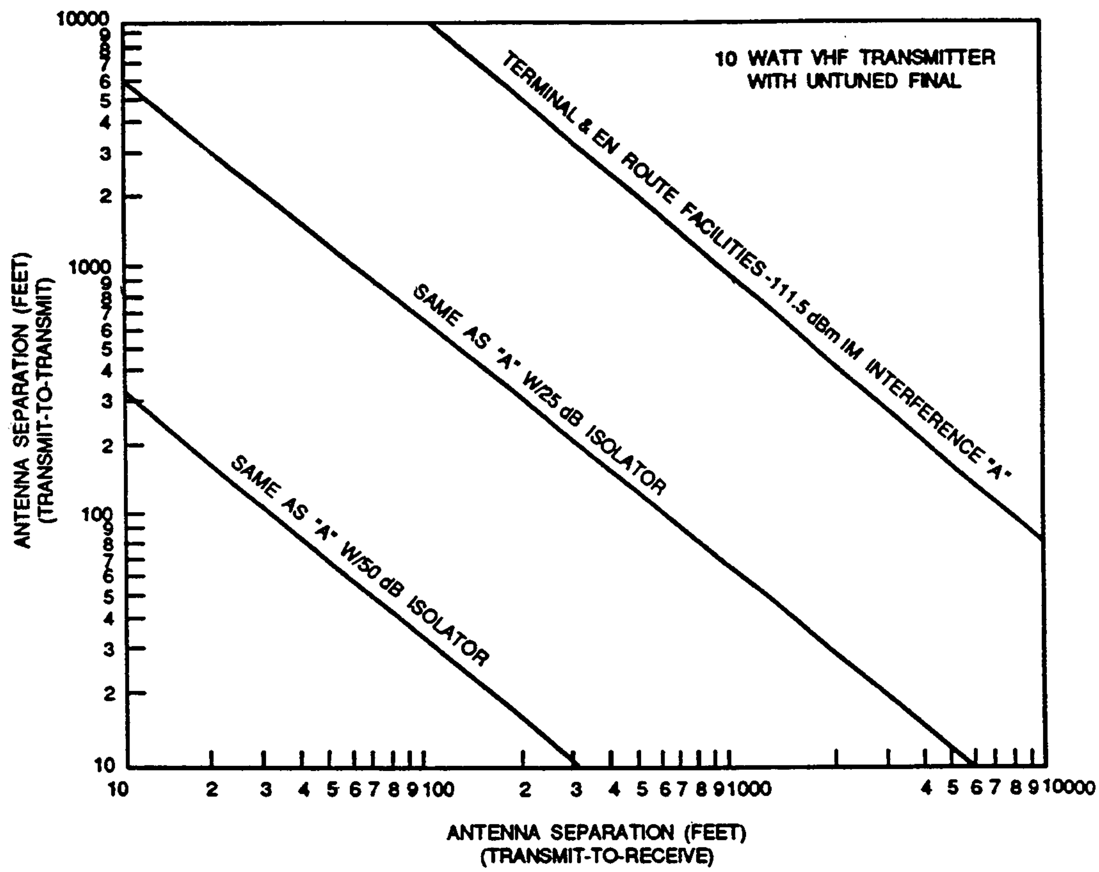


FIGURE 12. ANTENNA SPACING TO AVOID INTERMODULATION INTERFERENCE (VHF TX - TUNED FINAL)

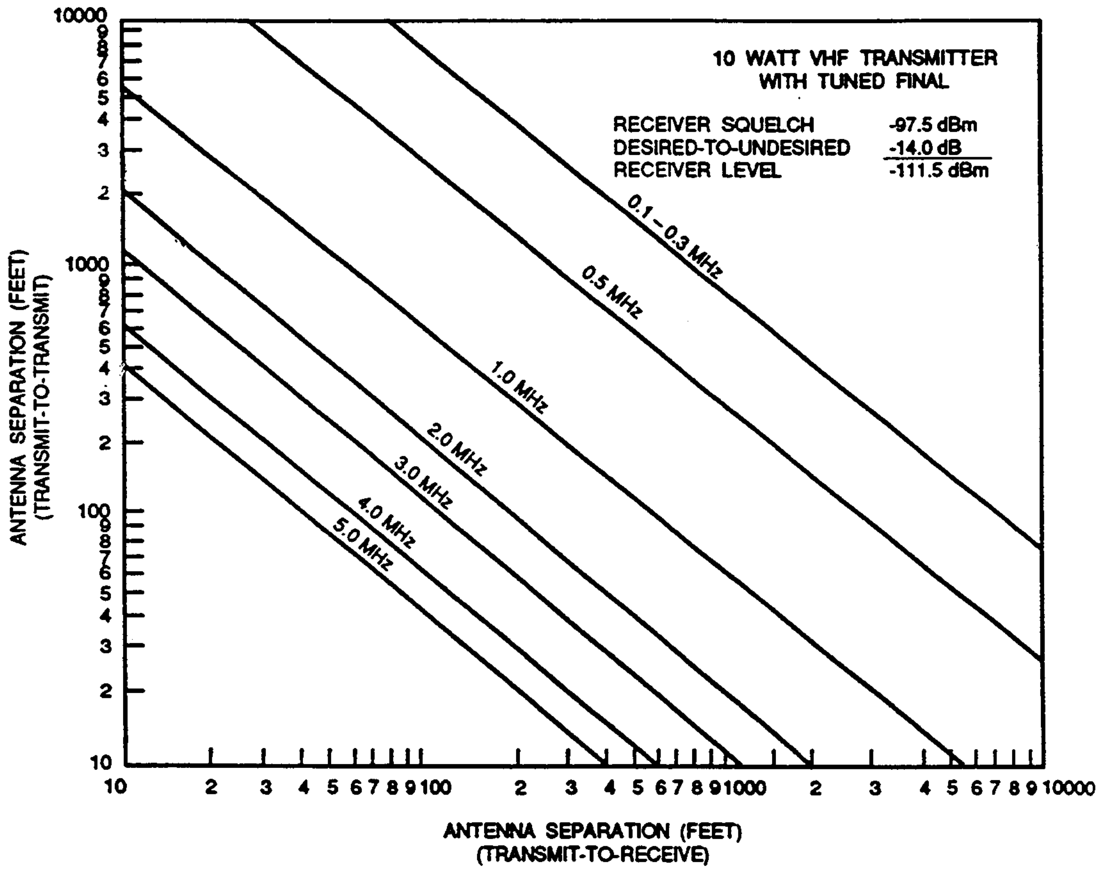


FIGURE 13. ANTENNA SPACING TO AVOID INTERMODULATION INTERFERENCE (UHF TX - UNTUNED FINAL)

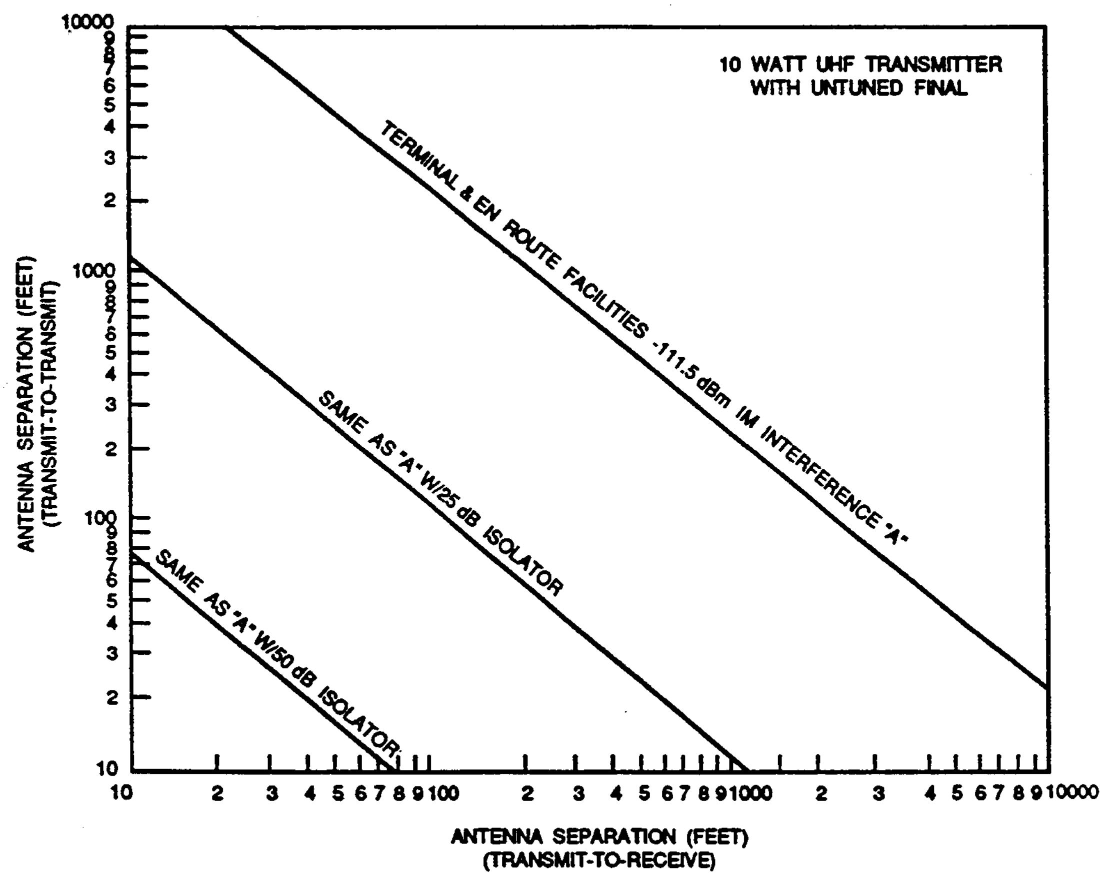


FIGURE 14. ANTENNA SPACING TO AVOID INTERMODULATION INTERFERENCE (UHF TX - TUNED FINAL)

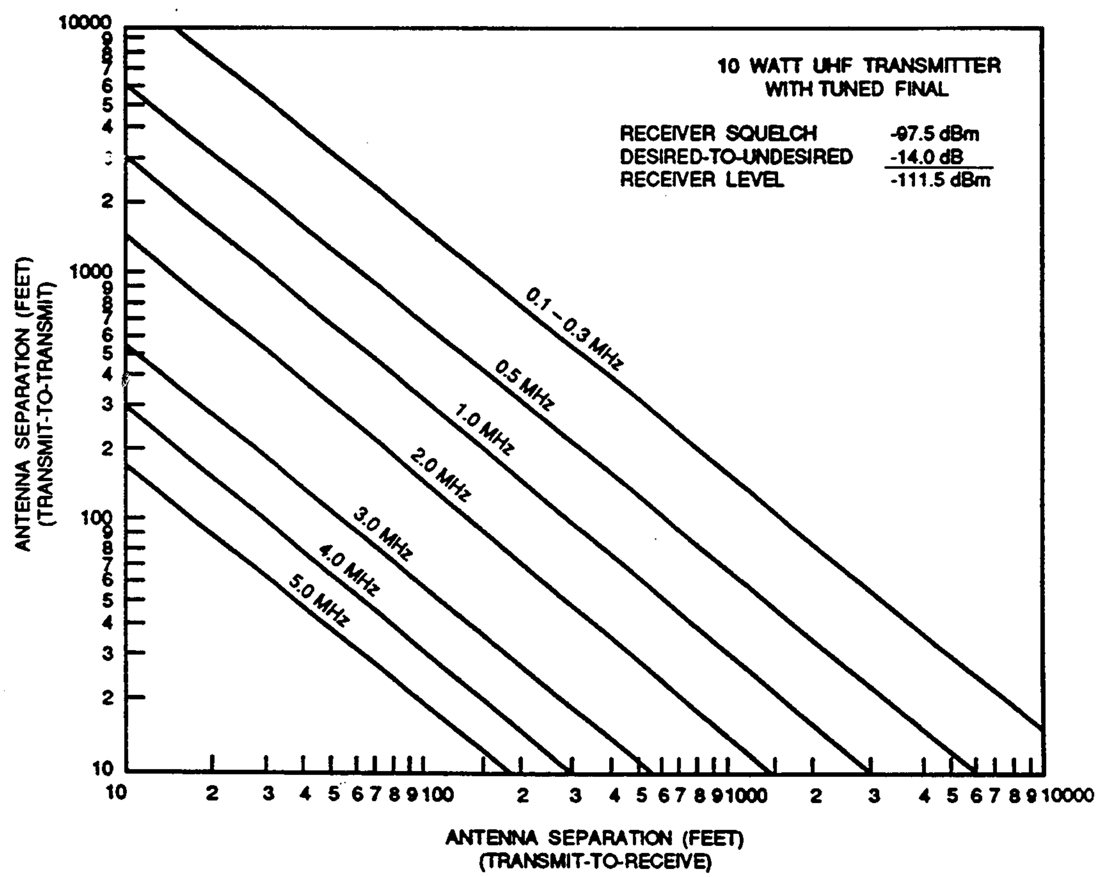


FIGURE 15. ANTENNA SPACING TO AVOID INTERMODULATION INTERFERENCE (VHF TX - LPA WITH TUNED CAVITY)

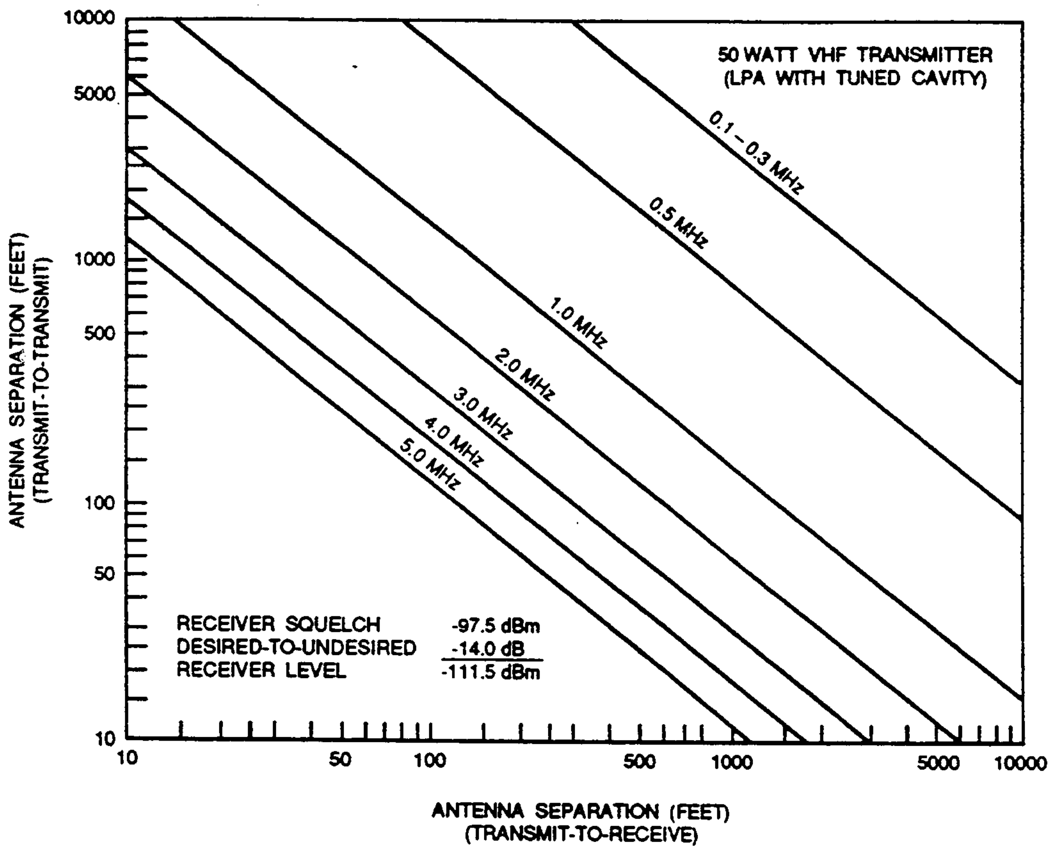
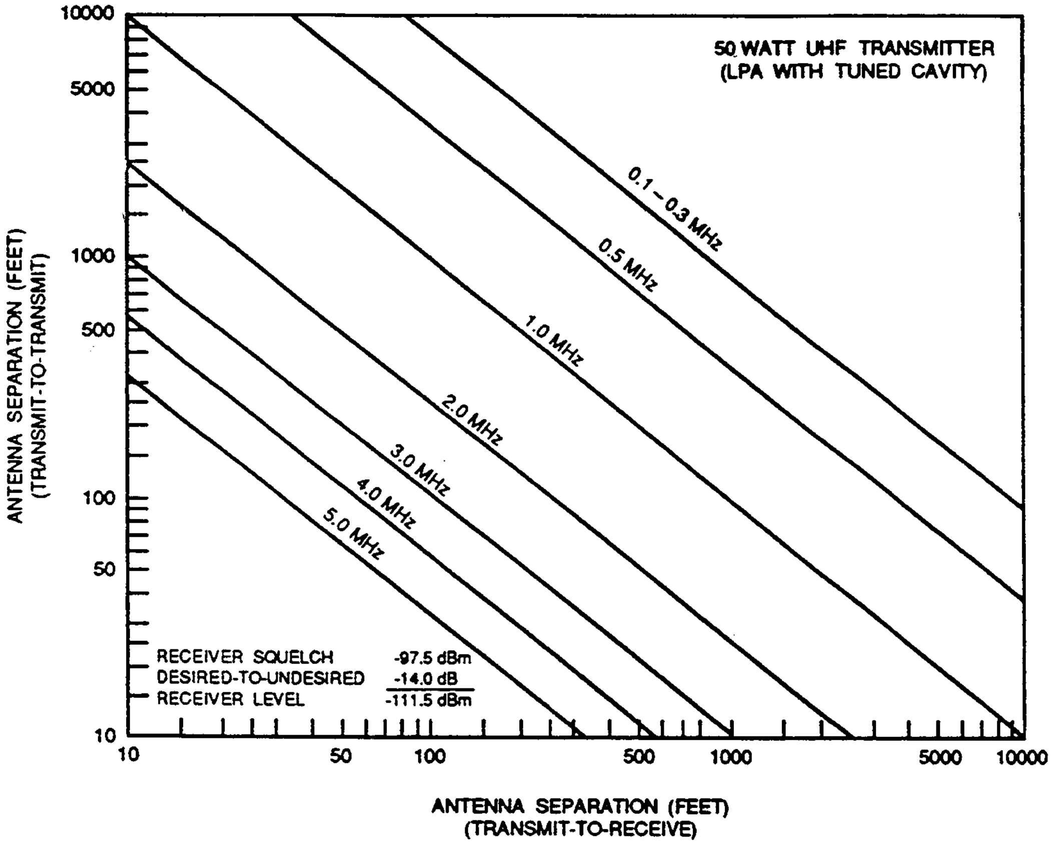


FIGURE 16. ANTENNA SPACING TO AVOID INTERMODULATION INTERFERENCE (UHF TX - LPA WITH TUNED CAVITY)



referring to figure 15, assume that IM products are occurring between 50 watt transmitters separated by 5 MHz. If the transmitter antennas are separated by 10 feet, the transmit-to-receive antenna spacings must be 150 feet. The elimination of transmitter IM interference usually will require greater antenna separation than that necessary to eliminate receiver desensitization. The latter will be accomplished in the process of eliminating transmitter IM interference. In some cases, ferrite isolators can be used to reduce transmitter IM interference and to permit closer spacing of antennas. Receiver desensitization should be checked independently.

> **NOTE:** The curves on figures 11 through 16 are used to perform rapid preliminary estimates of transmitter IM product interference and examination of possible remedies.

The following procedures can be used to verify the results obtained from the graphic curves. Add the four decibel values as follows:

Additional attenuation required (from graph, see NOTE)	_______dB
Transmitter IM attenuation (22 dB untuned, 24 tuned)	_______dB
Transmitter-to-transmitter space loss (figure 17)	_______dB
Transmitter-to-receiver space loss (figure 17)	_______dB

Total should be:

151.5 ± 3 dB for 10 watt transmitter	_______dB
158.8 ± 3 dB for 50 watt transmitter	_______dB

19. **ANTENNA SPACING AND FREQUENCY SEPARATION GUIDELINES**. See appendix 8 of this document for detailed derivation. The antenna spacing curves for receiver desensitization and transmitter IM product reduction shown in figures 9 through 16, can be used to achieve any degree of freedom from interference. Antenna transmitter-to-receiver spacing for IM reduction is over 10,000 feet, when the two transmitter antennas are within 8 feet of each other. If the interference becomes a problem, ferrite isolators can be added for reduction of transmitter intermodulation product interference. If the antennas are close enough to cause desensitization, filter devices can be added to the receivers. When interference becomes detrimental to critical communications, either the antennas must be moved or new frequency assignments requested.

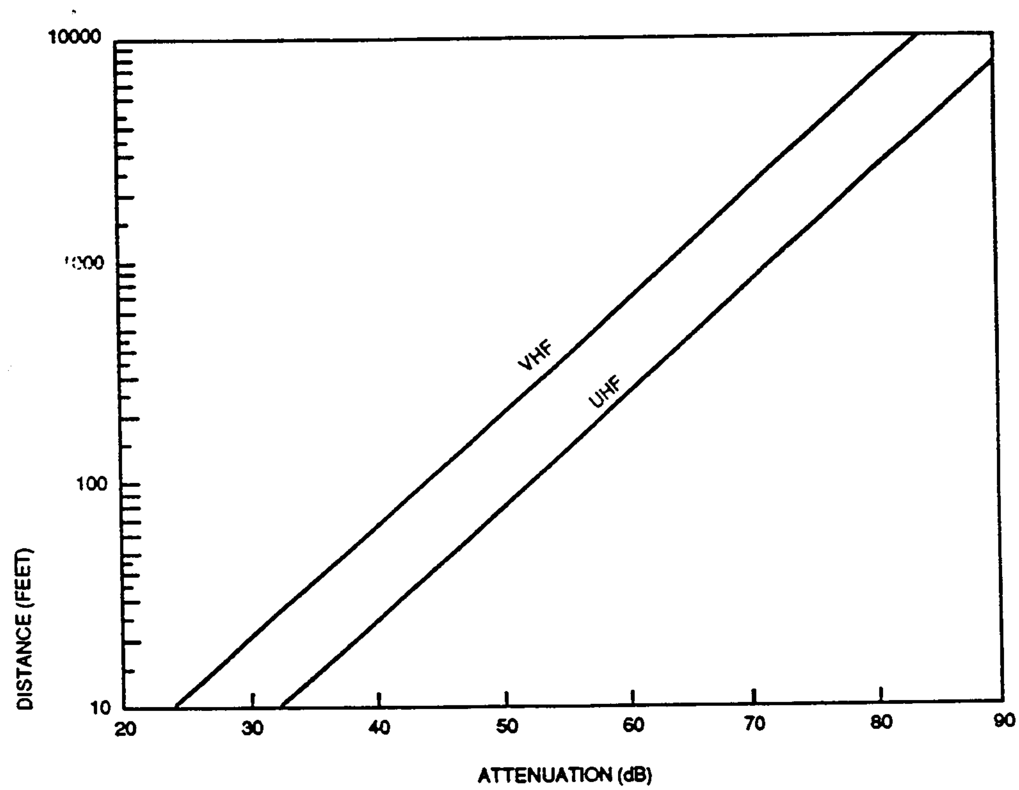
a. **Intermodulation Product Free Space Attenuation**. When the intercept is not on a curve, figure 17 interpolates for the decibel value of the transmitter-to-transmitter and transmitter-to-receiver intercept on the IM interference, figures 11 through 16. For example, if the transmitter-to-transmitter distance is 21 feet and the transmitter-to-receiver distance is 80 feet, the intercept is to the left of the 50 dB curve on figure 11 and you will have severe interference even with ferrite isolators. Follow along the 21 foot ordinate (figure 11) to the 50 dB curve and note the distance shown on the abscissa (approximately 154 feet). Using figure 17, convert this distance to decibels (VHF curve, 48 dB). Then convert 80 feet to decibels (42 dB). Take the difference between these values (6 dB) and add it to the 50 dB curve, making the value of the intercept 56 dB. This is the attenuation required to reduce the IM products to -111.5 dBm, taking into account that ferrite isolators are already installed.

NOTE: The IM product interference graphs start with the upper right-hand curve which represents the nominal internal IM product attenuation of the transmitter final amplifier. As additional attenuation is added by using isolators or tuned cavities, the new curves appear to the left. In figures 11 and 13, the attenuation obtained from the curves on the graph indicates the isolator attenuation required to reduce the interference to a level of -111.5 dBm. In figures 12, 14, 15, and 16, the attenuation indicated on these graphs is equivalent to about a single cavity tuned near the point of lowest insertion loss or broadest tuning, and includes the internal IM product loss that is due to the mixing action in the final amplifier. Note that a tuned cavity equally attenuates the incoming signal and the outgoing IM product. Therefore, if a "tuned cavity" chart shows a requirement for 12 dB additional attenuation, the cavity needs to be adjusted only a 6 dB increase in attenuation to accomplish the 12 dB attenuation requirement. The curves on the "tuned cavity" graphs are about halfway between the values for single cavity at 0.5 dB insertion loss and 1.0 dB insertion loss, as shown in table 19 of appendix 8. This reference provides a basis for judging whether or not retuning may be a logical approach for effectively reducing the IM product level.

b. Interpolation of IM Product Graphs. Values other than those represented by the curves on figures 11 through 16 can be obtained by using figure 17 and following the procedure described in paragraph 19a, Intermodulation Product Attenuation Interpolation.

20. **RECEIVER SPURIOUS RESPONSE ELIMINATION**. Spurious responses from a receiver are caused by the receiver oscillator spurious products. The frequency of the interfering transmitter must be correct for mixing with the receiver local oscillator spurious product in such a way as to produce a signal at the image frequency of the receiver, or on the desired channel frequency of the receiver.

FIGURE 17. INTERMODULATION PRODUCT FREE SPACE ATTENUATION INTERPOLATION GRAPH



21. <u>**BROADCAST STATION INTERFERENCE**</u>. VHF/FM broadcast station interference is discussed in paragraph 6 of this appendix. It should be noted that high-powered medium frequency Amplitude Modulated (AM) broadcast transmitters can be the source of the intermodulation products generated at cold solder joints or other nonlinear areas in the receiver antenna or coaxial cable system. Figures 18, 19, 20, and 21 are provided herein for general reference.

22.-25. <u>**RESERVED**</u>.

FIGURE 18. COMPUTED RECEIVER FRONT-END PROFILE COMPARED TO SPECIFICATION

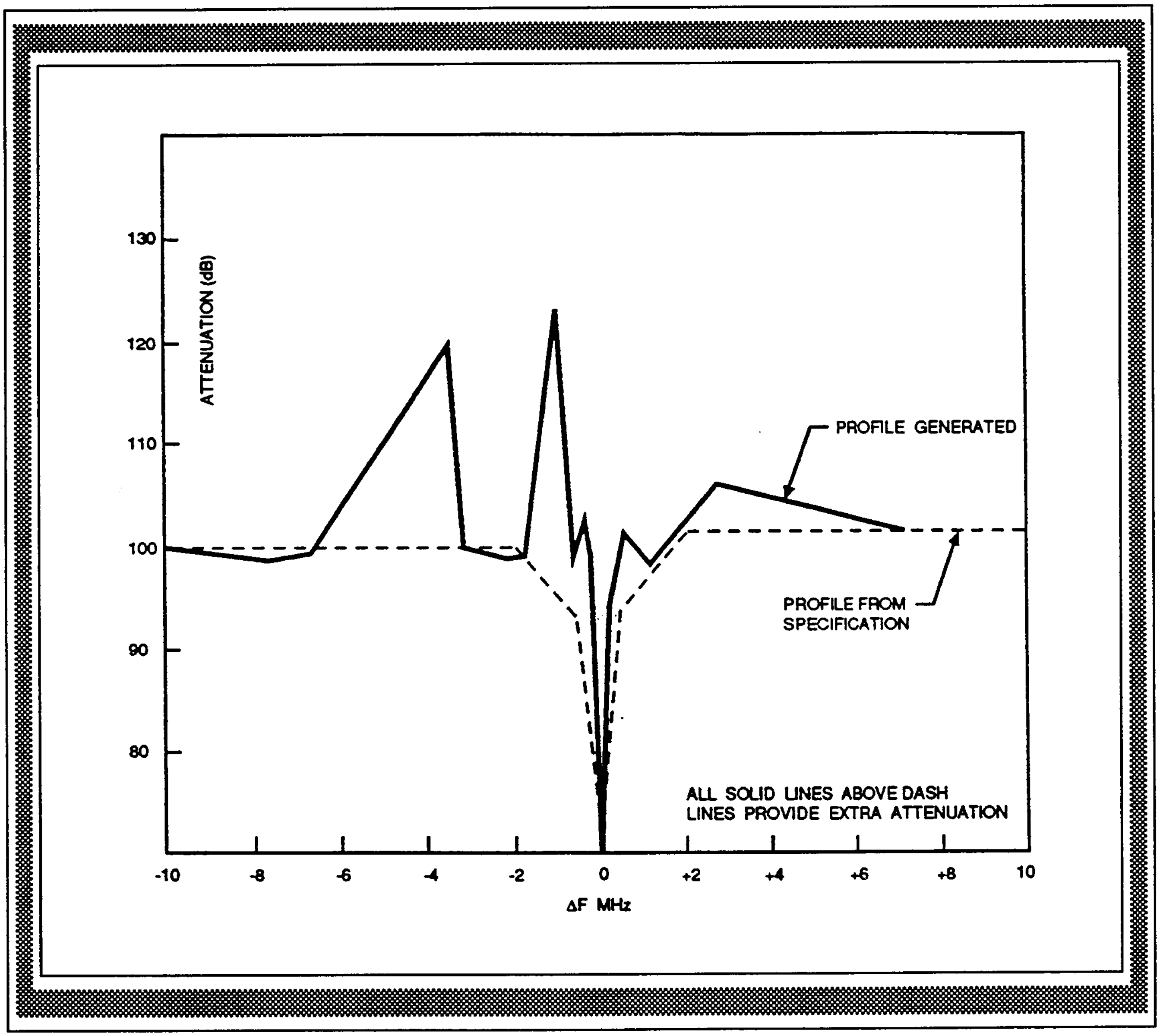


FIGURE 19. TYPICAL PATTERN DISTORTION CAUSED BY ANOTHER ANTENNA

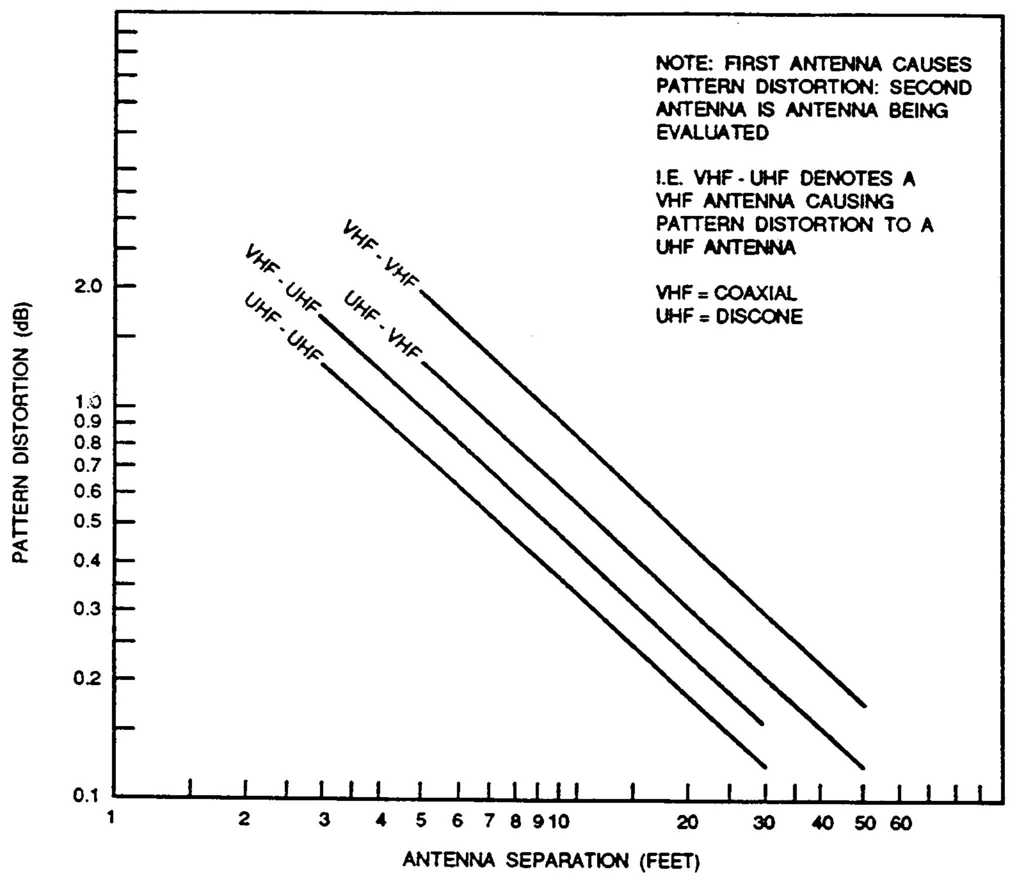


FIGURE 20. SLANT DISTANCE & EFFECTIVE APERTURE FOR STAGGERED ANTENNAS

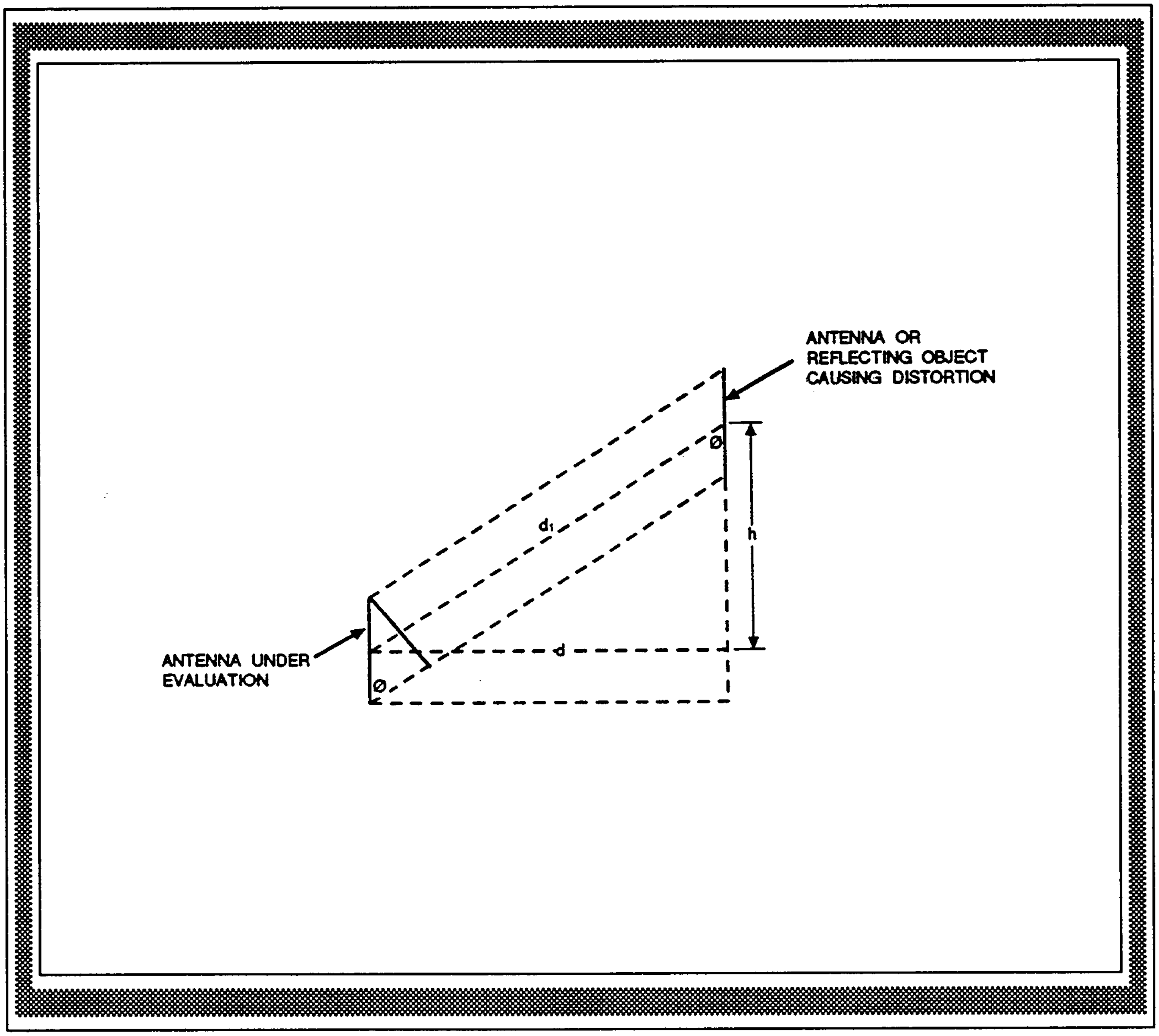
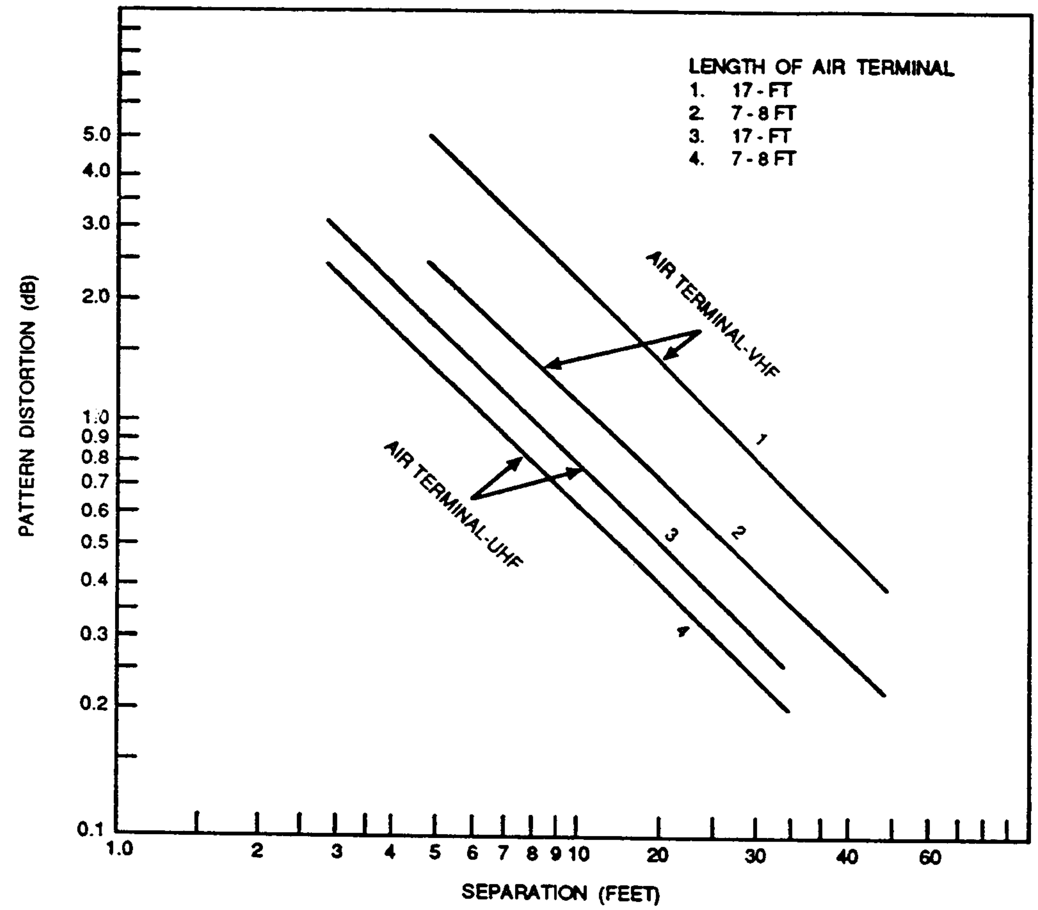


FIGURE 21. TYPICAL PATTERN DISTORTION CAUSED BY A VERTICAL CONDUCTING OBJECT



APPENDIX 6. VERTICAL LOBING

1. INTRODUCTION.

a. **Purpose**. This appendix is to provide a technique for determining a compromise height of a ground-based antenna over various types of terrain which will provide a required quality of communications over a specified volume of airspace.

b. **Antenna Pattern Distortion**. Vertical lobing is a term applied to antenna distortion caused by propagation to or from a ground-based antenna which travels simultaneously over a desired direct path and a ground-reflected path, shown in Figure 22, Geometry of Direct and Reflected Propagation Paths. When the signals over the two paths are combined, constructive or destructive interference occurs, depending upon the height of the two antennas; the distance between the antennas, antenna efficiency and the terrain characteristics at the ground reflection point; and the transmit frequency. The pattern of peaks and nulls which occurs in any vertical plane appears as vertical lobing. If the distortion due to the multiple propagation paths is treated as if it were contained in the ground antenna, then it can be assumed that only a direct path exists between the ground and aircraft antennas. The vertical pattern shown in Figure 23, Example of Vertical Pattern with Vertical Lobing Distortions (Shown for Flat Earth), illustrates the effect of combining the vertical lobing distortions into a broad antenna pattern.

c. **Propagation Geometry**. Because the geometry of the paths and the properties of the ground reflection point are the same whether the ground antenna is transmitting or receiving energy (law of reciprocity), the vertical lobing pattern shown in figure 23 is identical in shape for both the transmit or receive case. Figure 23 represents a vertical plane through the aircraft and ground antennas. When the ground antenna is transmitting, the contour shown represents all points where the aircraft will receive 12 uV at the input to its receiver input. This signal level is present when the transmitter power output of the coaxial transmission line feeding the antenna is 6 watts. This appendix describes a method for determining graphically the positions and depths of the nulls in the vertical patterns for a ground transmit antenna. Modification of this technique for the receive case is described in paragraph 4 of this appendix.

2. ASSUMPTIONS AND NOMINAL VALUES.

a. **Method Parameters**. In developing the method to be presented, the following parameters were assumed to make the method particularly applicable to conditions normally found in FAA A/G communications.

FIGURE 22. GEOMETRY OF DIRECT AND REFLECTED PROPAGATION PATHS

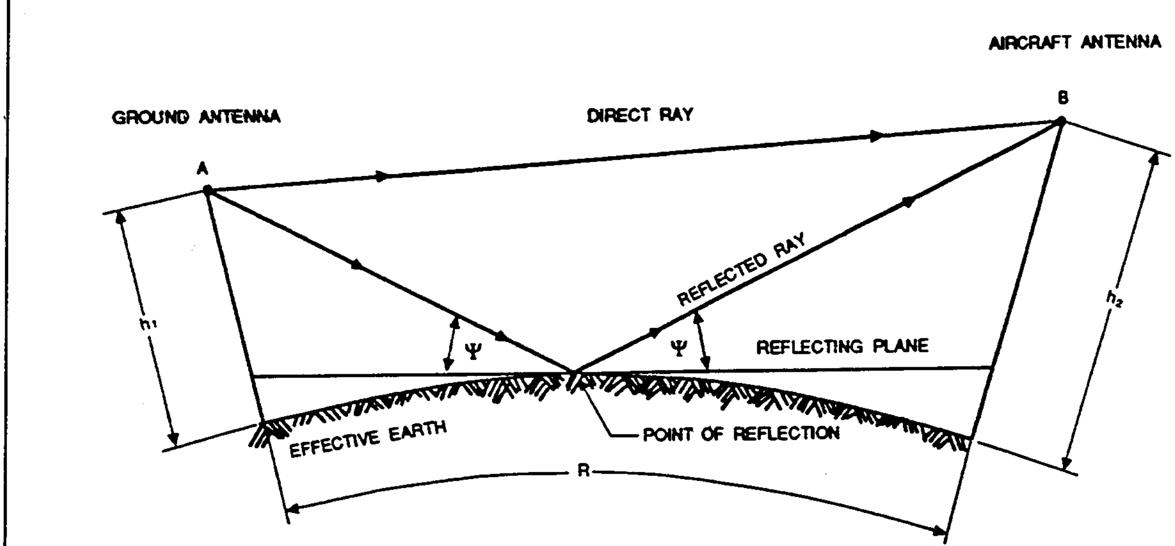
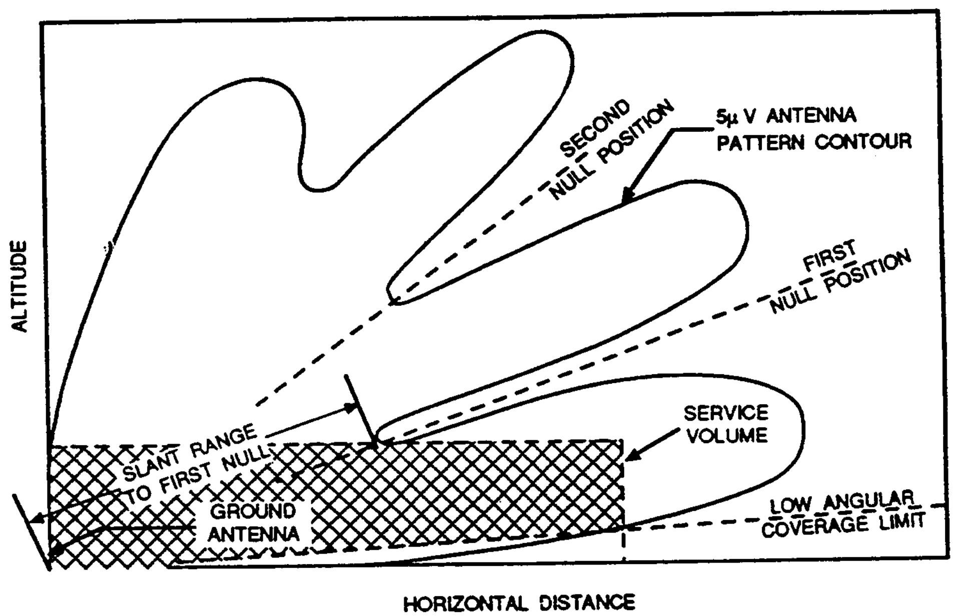


FIGURE 23. EXAMPLE OF VERTICAL PATTERN WITH VERTICAL LOBING DISTORTIONS (SHOWN FOR FLAT EARTH)



1. LOBES: VHF (127 MHz). ONE LOBE FOR EVERY 4 FEET ANTENNA IS ABOVE THE GROUND AT 20 FEET ABOVE GROUND, THERE WOULD BE FIVE LOBES.
2. LOBES: UHF (330 MHz). THERE WILL BE ONE LOBE GENERATED FOR EVERY 1.5 FEET THE ANTENNA FEED POINT IS LOCATED ABOVE GROUND, I.E., 13.4 LOBES AT 20 FEET.

(1) Vertical polarization.

(2) Frequency limits of 118 and 137 MHz.

(3) Spherical earth.

(4) Six classes of reflection material:

(a) Average soil: $\epsilon_r = 15$, $\sigma = 0.005$ mhos/meter.

(b) Dry desert soil: $\epsilon_r = 2$, $\sigma = 10^{-5}$ mhos/meter.

(c) Seawater: $\epsilon_r = 81$, $\sigma = 5$ mhos/meter.

(d) Good ground: $\epsilon_r = 25$, $\sigma = 0.02$ mhos/meter.

(e) Marshland: $\epsilon_r = 30$, $\sigma = 0.01$ mhos/meter.

(f) Freshwater: $\epsilon_r = 81$, $\sigma = 0.01$ mhos/meter.

Where ϵ is the relative dielectric constant and σ is the conductivity of the soil.

(5) Receiver input impedance of 50 ohms.

(6) Communications with aircraft under 0.09 degree above the horizon will not be considered. The angle from a site at 1,000 feet Above Mean Sea Level (AMSL) to an aircraft at 130 nautical miles and 18,000 feet AMSL is 0.49 degrees. For an aircraft at 40 nautical miles and 1,000 feet above the site, the vertical angle is 0.09 degrees.

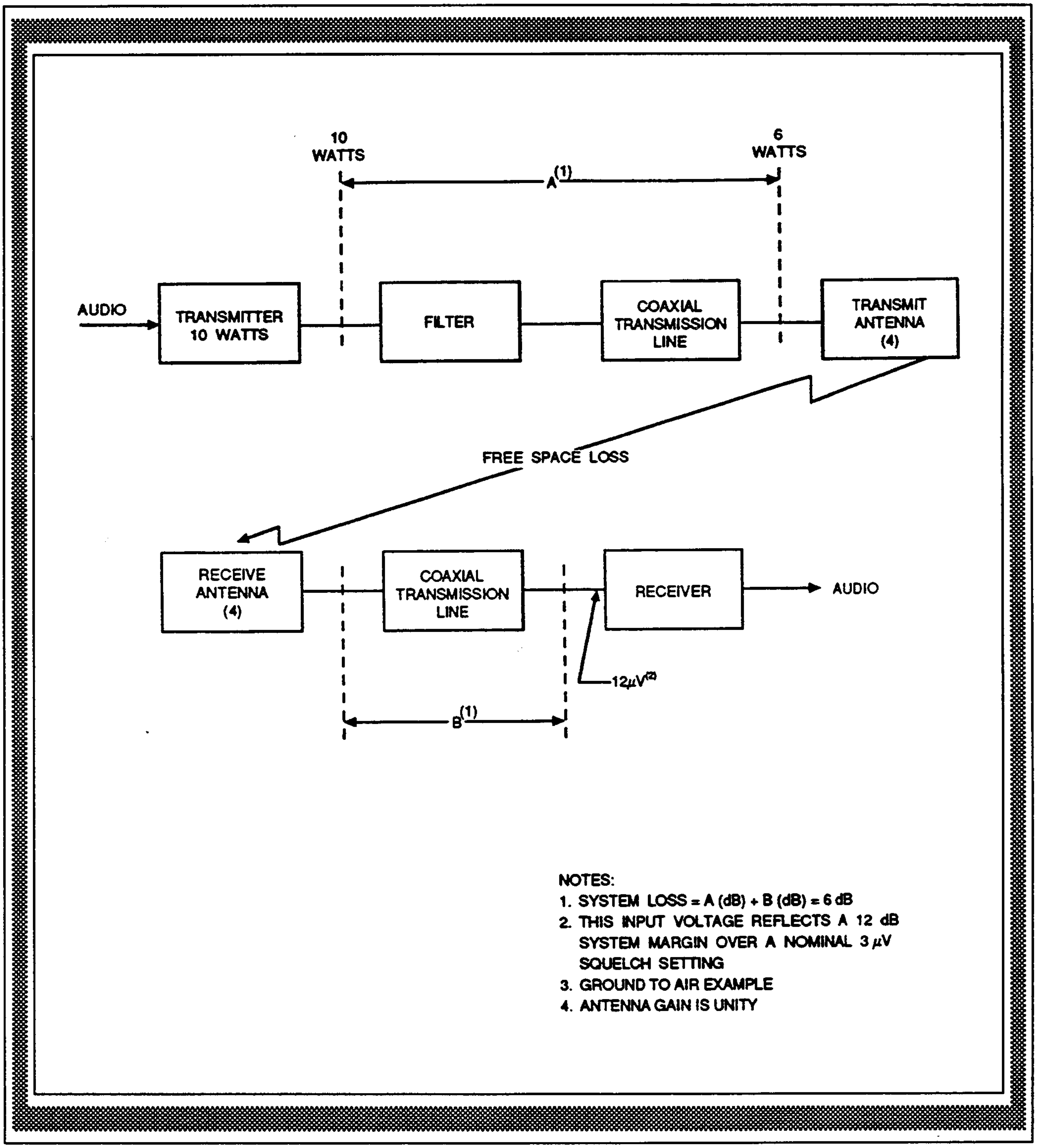
b. The graphs developed for this appendix are based upon assumed nominal values illustrated in Figure 24, Nominal Values for a Communications Link, and identified as follows:

(1) A terminal facility with a rated transmitter power of 10 watts with associated losses which reduce the power to 6 watts at the output to the coaxial transmission line feeding the transmit antenna.

(2) A system loss (at the transmitter plus that at the receiver) of 6 dB, as illustrated in figure 24.

(3) A required minimum receiver input voltage of 12 uV. Since this voltage is four times the normal 3 uV squelch setting, the requirement of 12 uV input to the receiver represents a 12 dB systems margin (or safety factor) in received signal level.

FIGURE 24. NOMINAL VALUES FOR A COMMUNICATIONS LINK



c. Other values of system parameters can be incorporated into the graphical method presented herein, as will be discussed in paragraph 4 of this appendix.

3. **METHOD TO DETERMINE GROUND ANTENNA ADEQUACY.**

a. **Communications Service Volume**. The method of determining whether the communications service volume is adequately served by the ground antenna consists of finding the range between the ground antenna and the 12 uV contour at the worst point in the pattern (the null of the pattern), finding the elevation angle of the null above the horizon, and evaluating whether the 12 uV contour at the null penetrates the communications service volume. For this method, several variables must be identified and defined. These include:

(1) Grazing angle, Ψ the angle of incidence and reflection at the earth's surface, as shown in figure 22.

(2) Ground antenna height, h_1, as shown in figure 22.

(3) Aircraft antenna height, h_2, as shown in figure 22.

(4) Distance (range), R, distance between transmit and receive antennas.

b. **Antenna Height Evaluation**. The process of evaluating the antenna height (h_1) to determine that the communications service volume is adequately served involves a seven-step process.

(1) **Step 1 - Service Volume**. A service volume requirements curve must be prepared using Figure 25, Graphical Aid for Determining Service Volumes, so the service volume can be depicted graphically, similar to that shown in Figure 26, Comparison Graph for Matching Lobe/Null Structure to Service Volume Requirements, and upon which nulls can be positioned to see if the service volume has been penetrated. Although it is unnecessary to plot a detailed vertical lobing pattern as shown in figure 26, the pattern does illustrate a nonpictorial graph of how it would appear.

(2) **Step 2 - Low Angle Coverage**. Low-angle coverage must be evaluated using Figure 27, Low-Angle Antenna Coverage Limits, to determine what antenna height satisfactorily covers the lower positions of the service volume down to the 0.4 degree limit.

(3) **Step 3 - First Null**. The position of the first (or higher) null must be determined for the particular terrain characteristics considered. Figure 28, Positions of Nulls vs Grazing Angle for Various Antenna Heights (Dry Dessert), is used if the reflection occurs on dry desert; Figure 29, Position of Nulls vs

FIGURE 25. GRAPHICAL AID FOR DETERMINING SERVICE VOLUMES

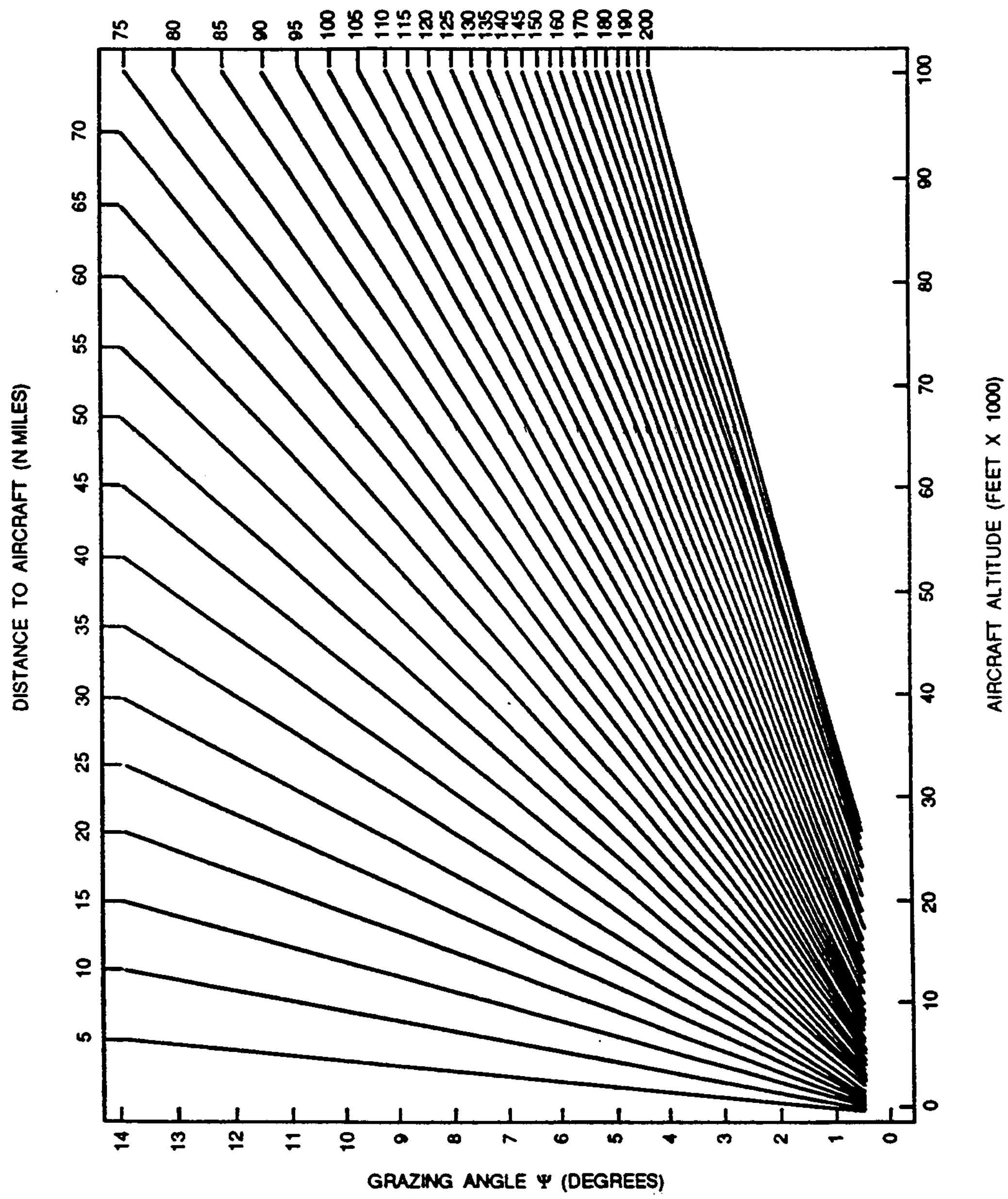


FIGURE 26. COMPARISON GRAPH FOR MATCHING LOBE/NULL STRUCTURE TO SERVICE VOLUME REQUIREMENTS

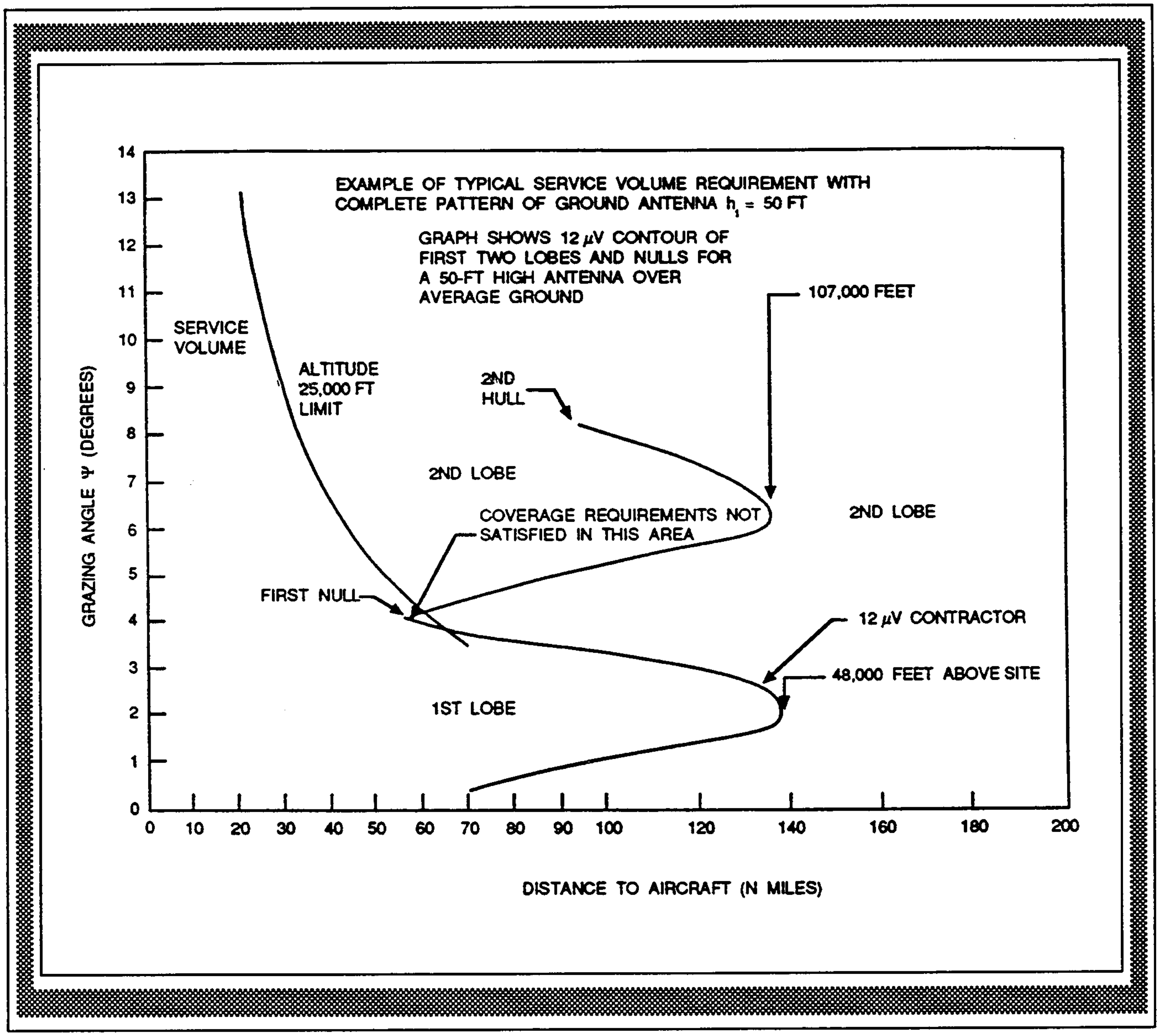


FIGURE 27. LOW-ANGLE ANTENNA COVERAGE LIMITS

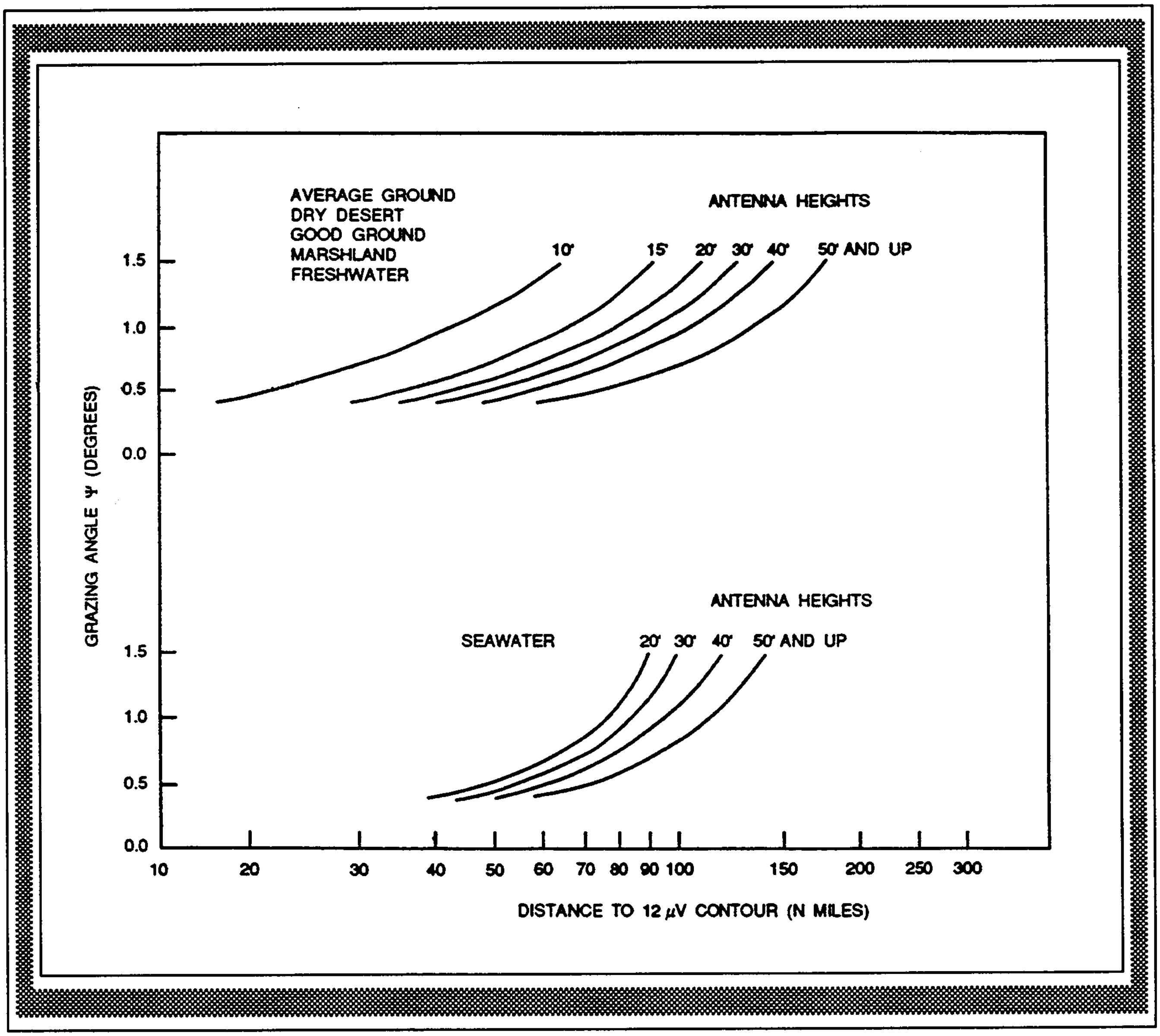


FIGURE 28. POSITION OF NULLS VERSUS GRAZING ANGLE FOR VARIOUS ANTENNA HEIGHTS (DRY DESERT)

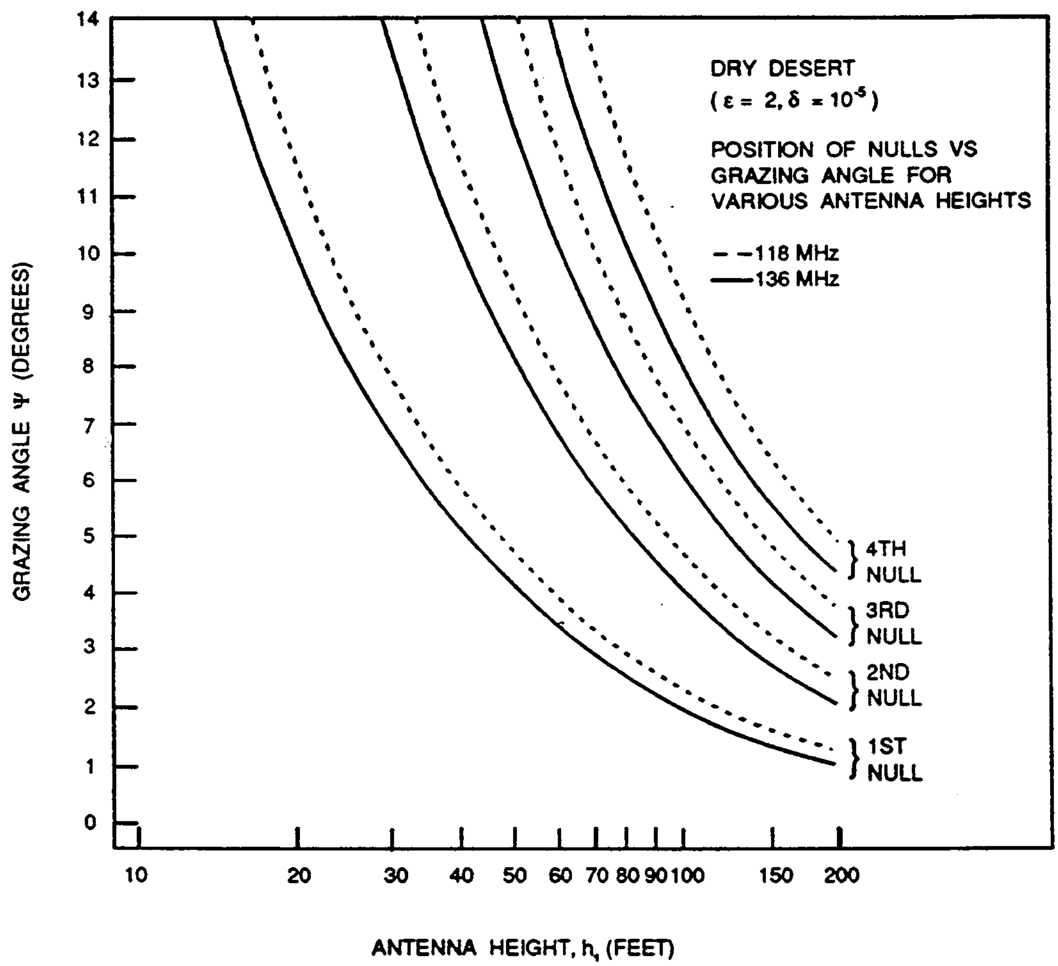


FIGURE 29. POSITION OF NULLS VERSUS GRAZING ANGLE FOR VARIOUS ANTENNA HEIGHTS (AVERAGE GROUND)

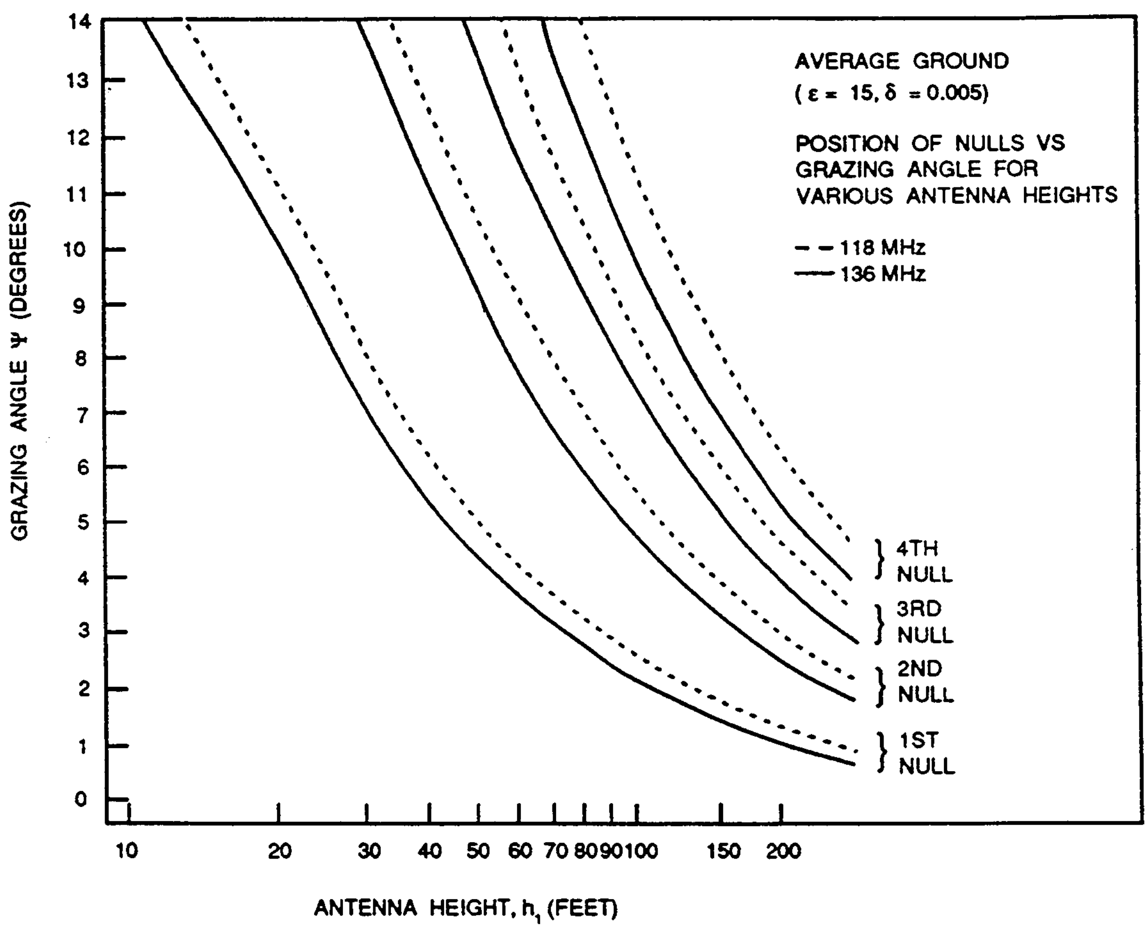


FIGURE 30. POSITION OF NULLS VERSUS GRAZING ANGLE FOR VARIOUS ANTENNA HEIGHTS (GOOD GROUND)

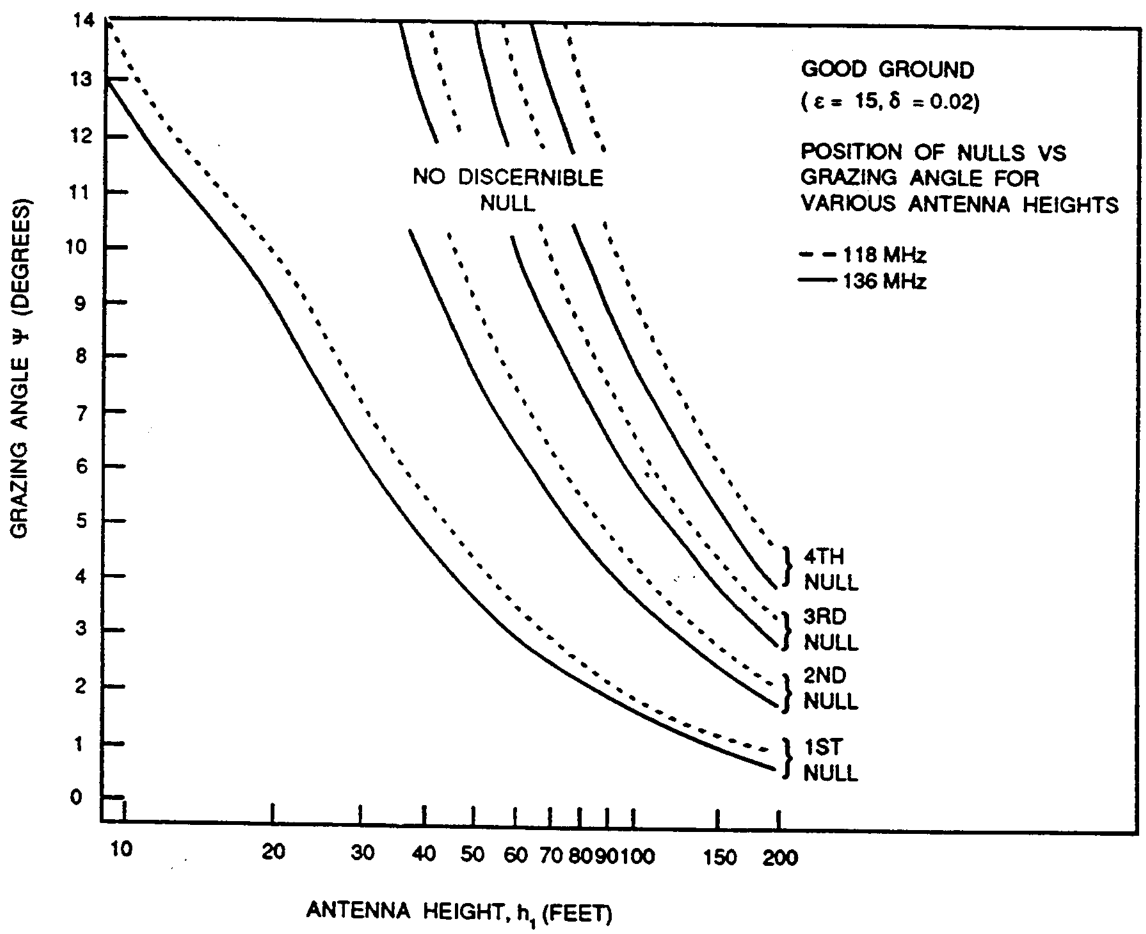
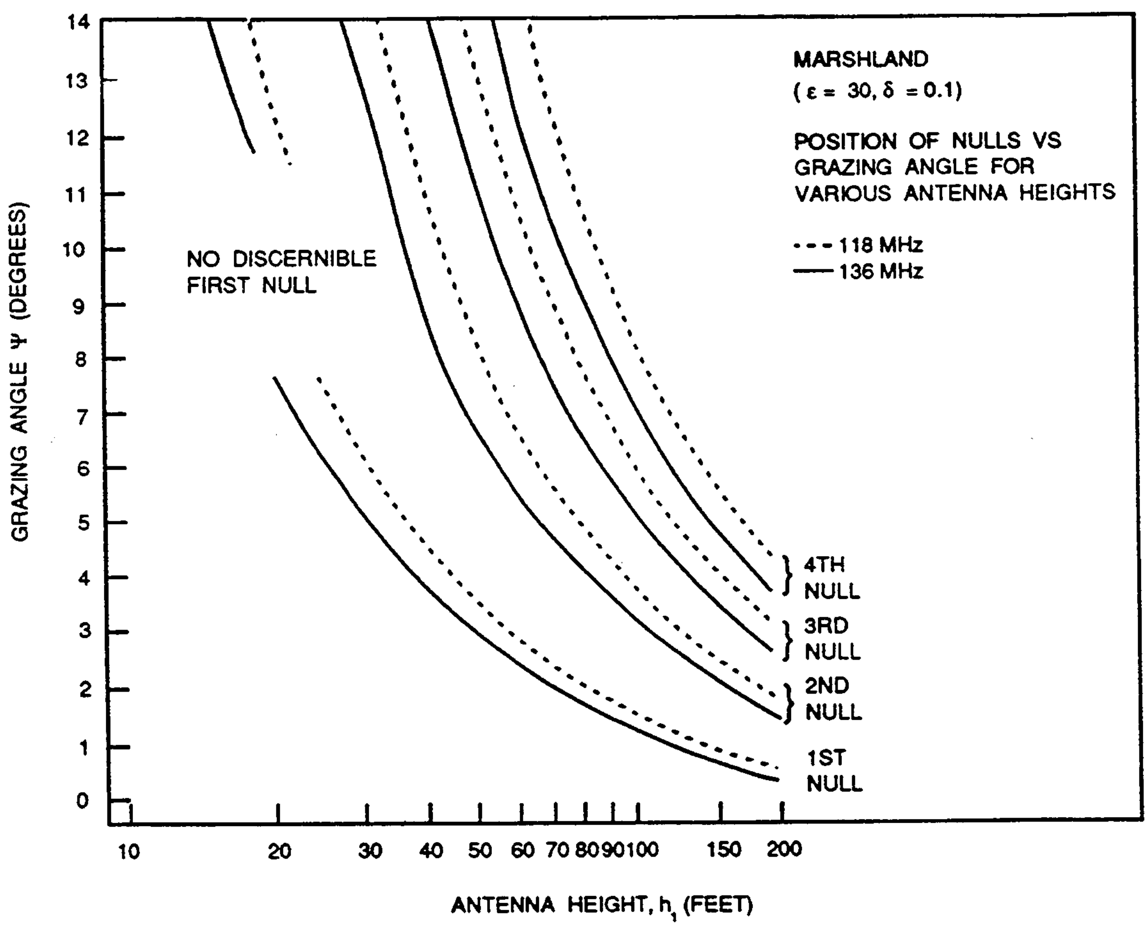


FIGURE 31. POSITION OF NULLS VERSUS GRAZING ANGLE FOR VARIOUS ANTENNA HEIGHTS (MARSHLAND)



Grazing Angle for Various Antenna Heights (Average Ground) for average ground; Figure 30, Position of Nulls vs Grazing Angle for Various Antenna Heights (Good Ground); Figure 31, Position of Nulls vs Grazing Angle for Various Antenna Heights (Marshland); Figure 32, Position of Nulls vs Grazing Angle for Various Antenna Heights (Freshwater); and Figure 33, Position of Nulls vs Grazing Angle for Various Antenna Heights (Sea Water).

(4) **Step 4 - Null Contour**. The distance to the null of the 12 uV contour must be determined using Figure 34, Distance to Nulls of 12 uV Contour for Various Grazing Angles (Dry Desert), if the reflection occurs on dry desert; Figure 35, Distance to Nulls of 12 uV Contour for Various Grazing Angles (Average Ground), if on average ground; Figure 36, Distance to Nulls of 12 uV Contour for Various Grazing Angles (Good Ground), if on good ground; Figure 37, Distance to Nulls of 12 uV Contour for Various Grazing Angles (Marshland), if on marshland; Figure 38, Distance to Nulls of 12 uV Contour for Various Grazing Angles (Freshwater) if on freshwater; and Figure 39, Distance to Nulls of 12 uV Contour for Various Grazing Angles (Seawater) if on seawater.

(5) **Step 5 - Results**. The results of steps 3 and 4 are plotted on the service volume curve prepared in step 1.

(6) **Step 6 - Renormalization**. If the ground antenna is to be used as a receive antenna rather than a transmit antenna, or if the values to be studied are different from those that have been assumed, a renormalization process must be used to adjust the new values to actual values. This renormalization process is presented in paragraph 4.

(7) **Step 7 - Gapless Coverage**. If the antenna height selected produces nulls which do not fall within the service volume and no other acceptable height is more available, then the requirement for gapless coverage is satisfied and the design procedures in this appendix are complete. If the antenna height does not meet the requirements, a new height should be attempted by returning to step 2 and repeating the process, or, if all heights are exhausted, the requirements for the communications service volume should be reevaluated.

c. **Renormalizing Techniques**. Paragraph 4, presents the techniques to renormalize the calculations to more appropriate values or to change conditions from a ground transmit antenna to a receive antenna. Paragraph 5 presents several examples envolving the method described.

FIGURE 32. POSITION OF NULLS VERSUS GRAZING ANGLE FOR VARIOUS ANTENNA HEIGHTS (FRESHWATER)

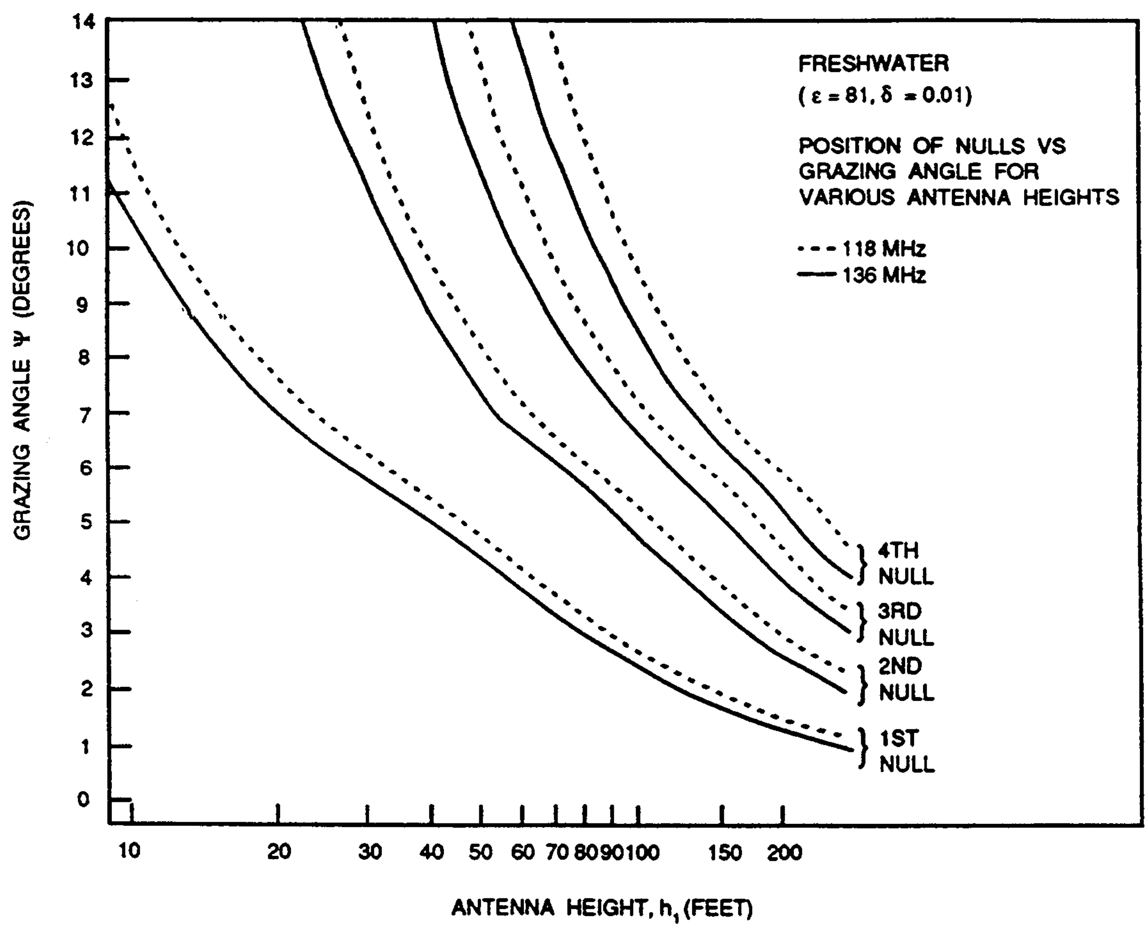


FIGURE 33. POSITION OF NULLS VERSUS GRAZING ANGLE FOR VARIOUS ANTENNA HEIGHTS (SEA WATER)

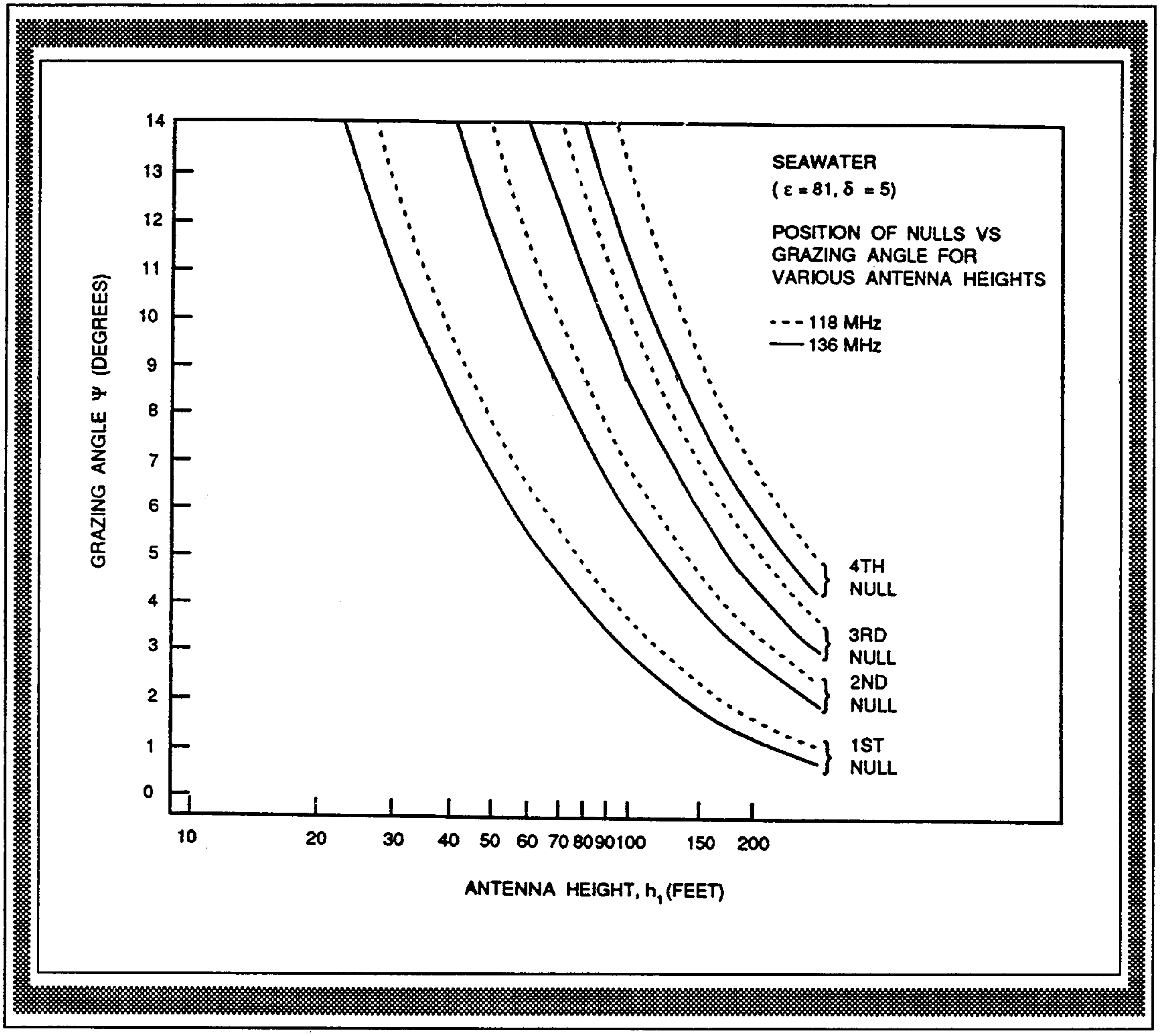


FIGURE 34. DISTANCE TO NULLS OF 12 uV CONTOUR FOR VARIOUS GRAZING ANGLES (DRY DESERT)

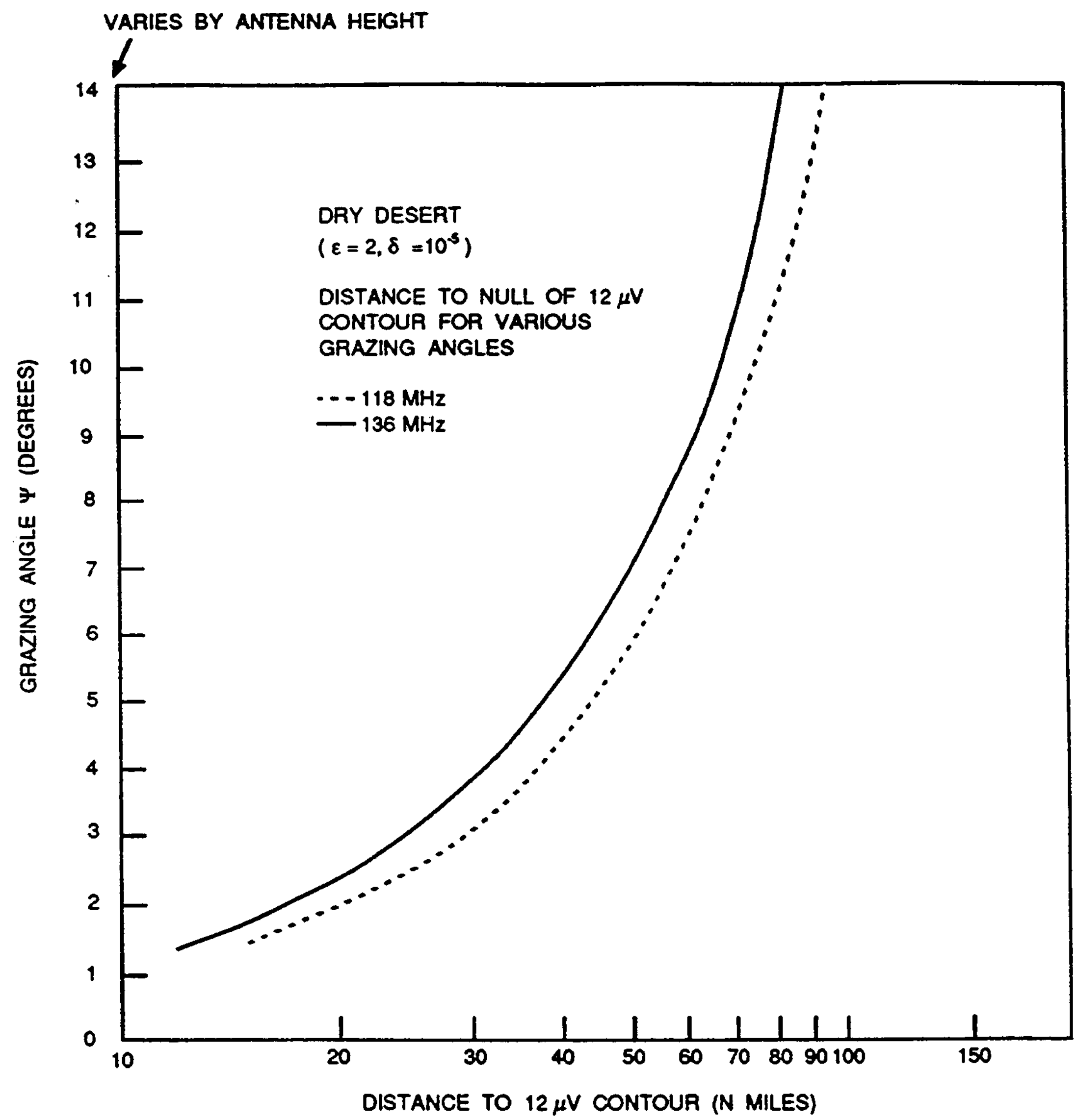


FIGURE 35. DISTANCE TO NULLS OF 12 uV CONTOUR FOR VARIOUS GRAZING ANGLES (AVERAGE GROUND)

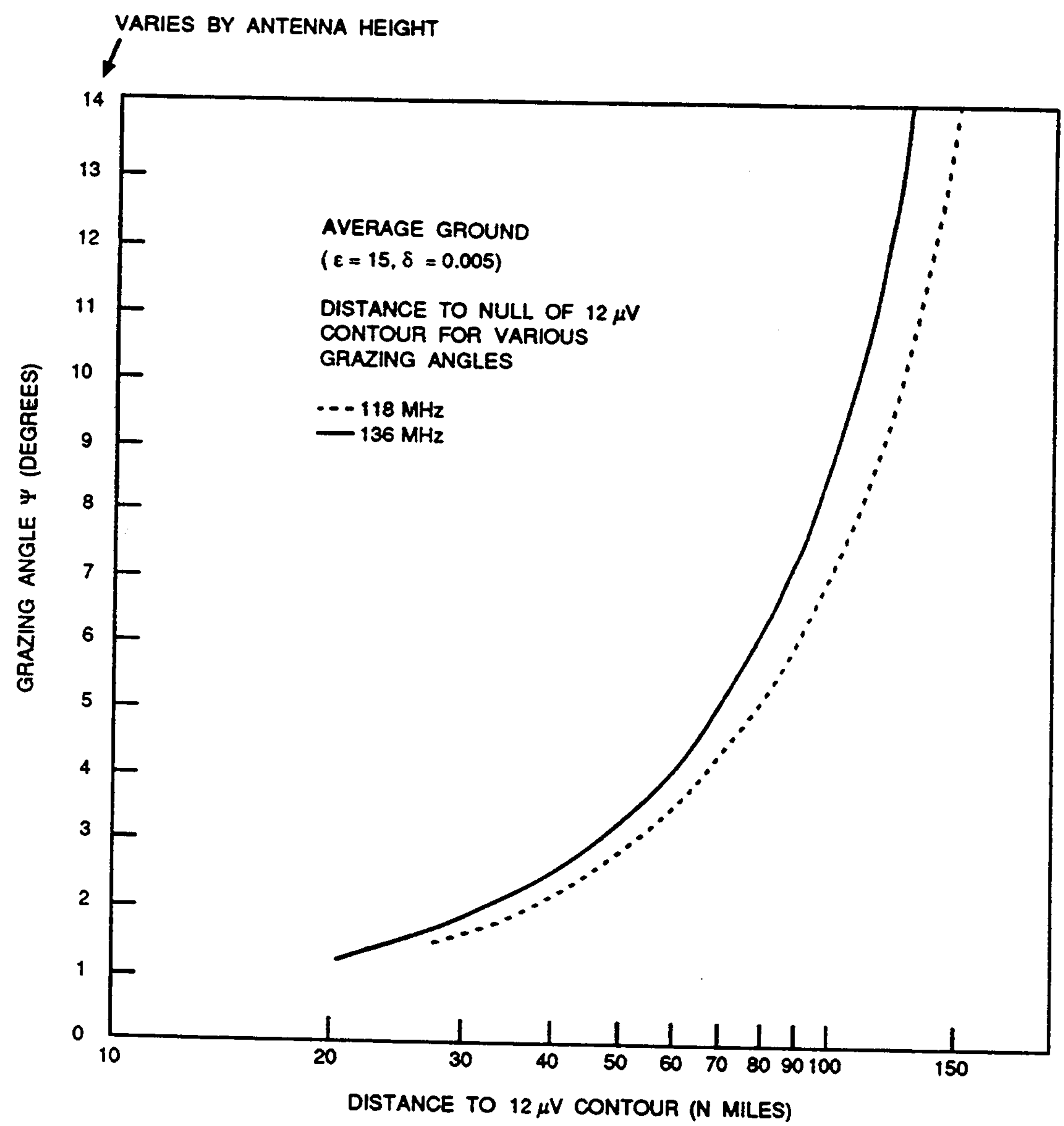


FIGURE 36. DISTANCE TO NULLS OF 12 uV CONTOUR FOR VARIOUS GRAZING ANGLES (GOOD GROUND)

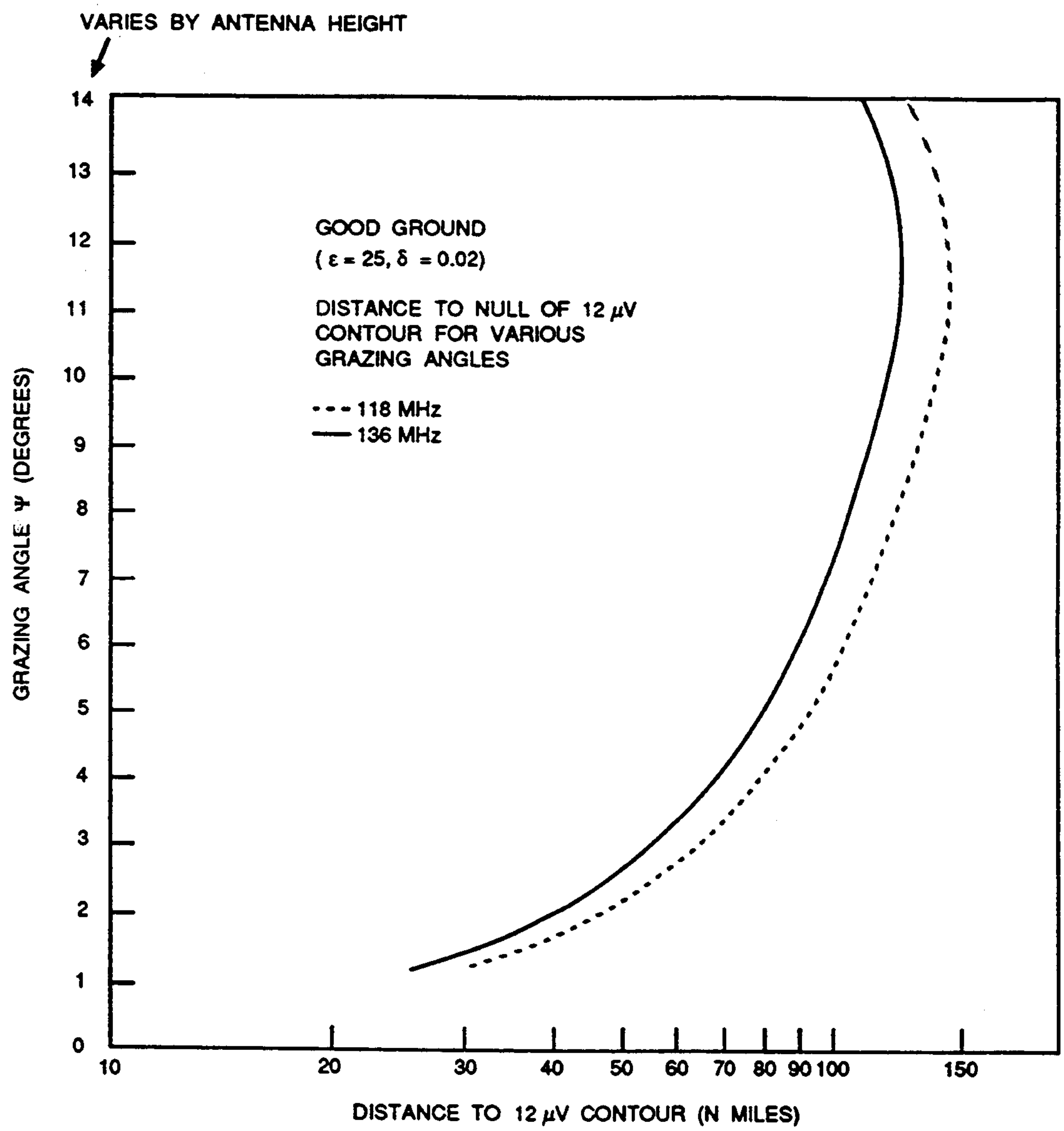


FIGURE 37. DISTANCE TO NULLS OF 12 uV CONTOUR FOR VARIOUS GRAZING ANGLES (MARSHLAND)

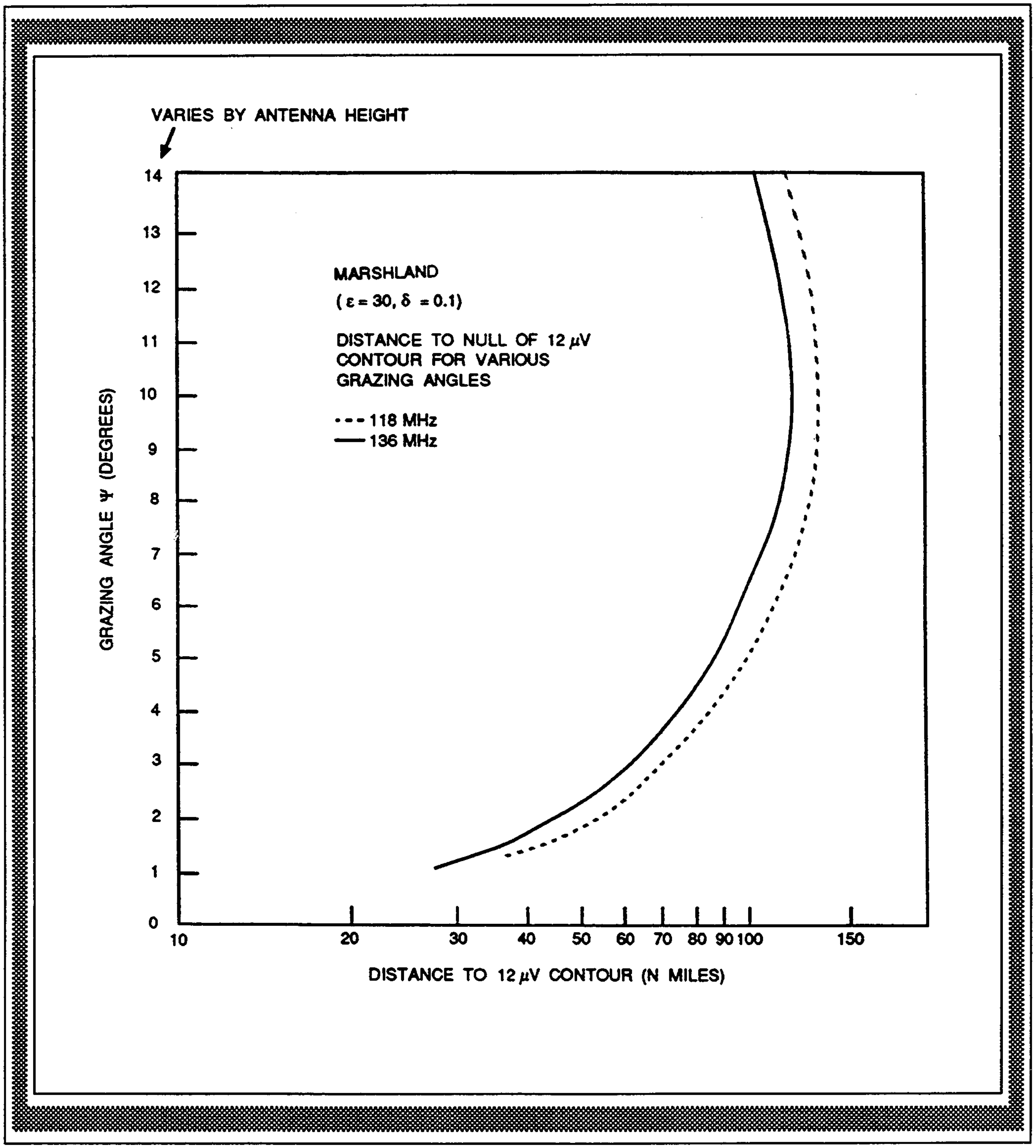


FIGURE 38. DISTANCE TO NULLS OF 12 uV CONTOUR FOR VARIOUS GRAZING ANGLES (FRESHWATER)

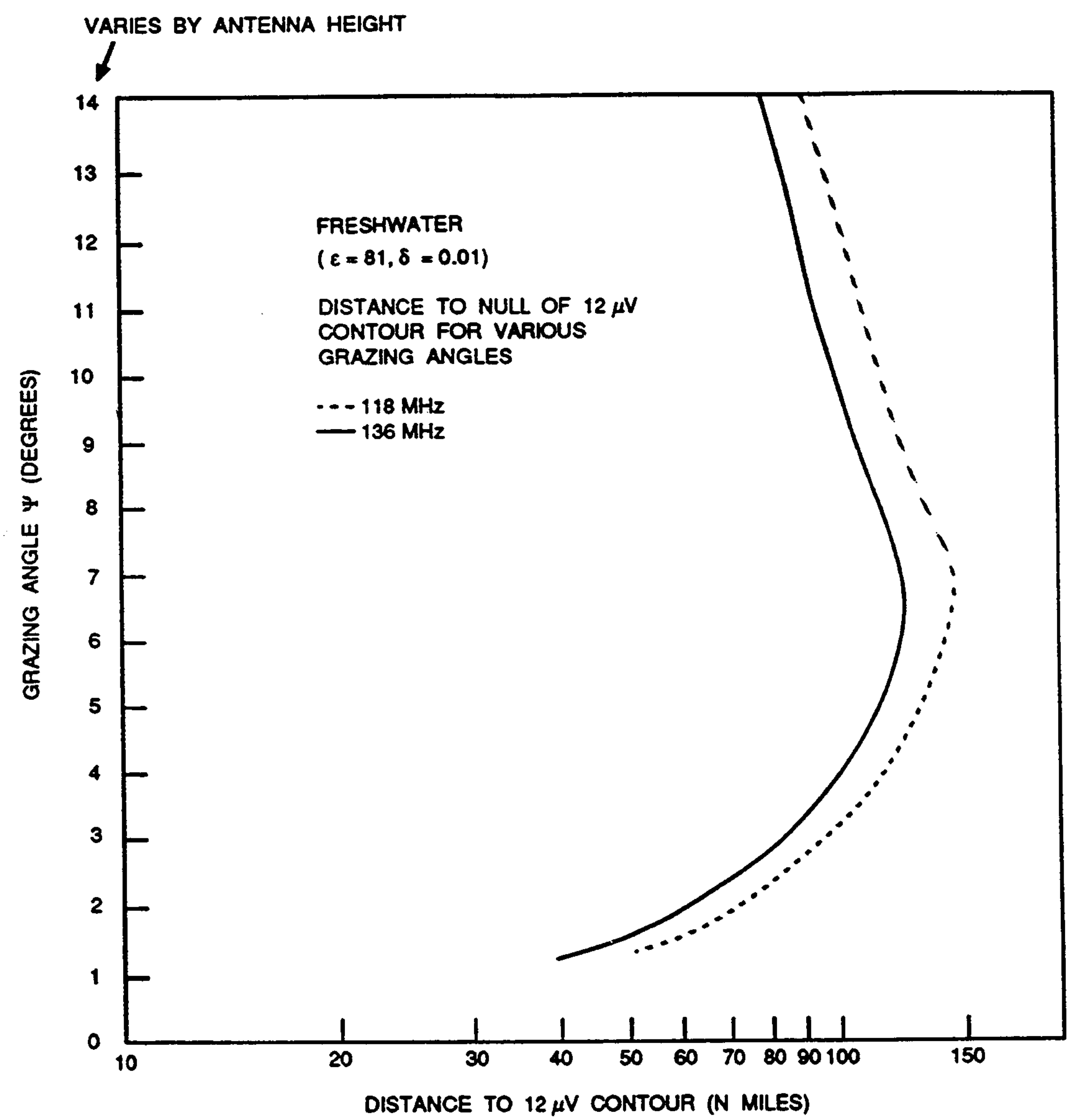
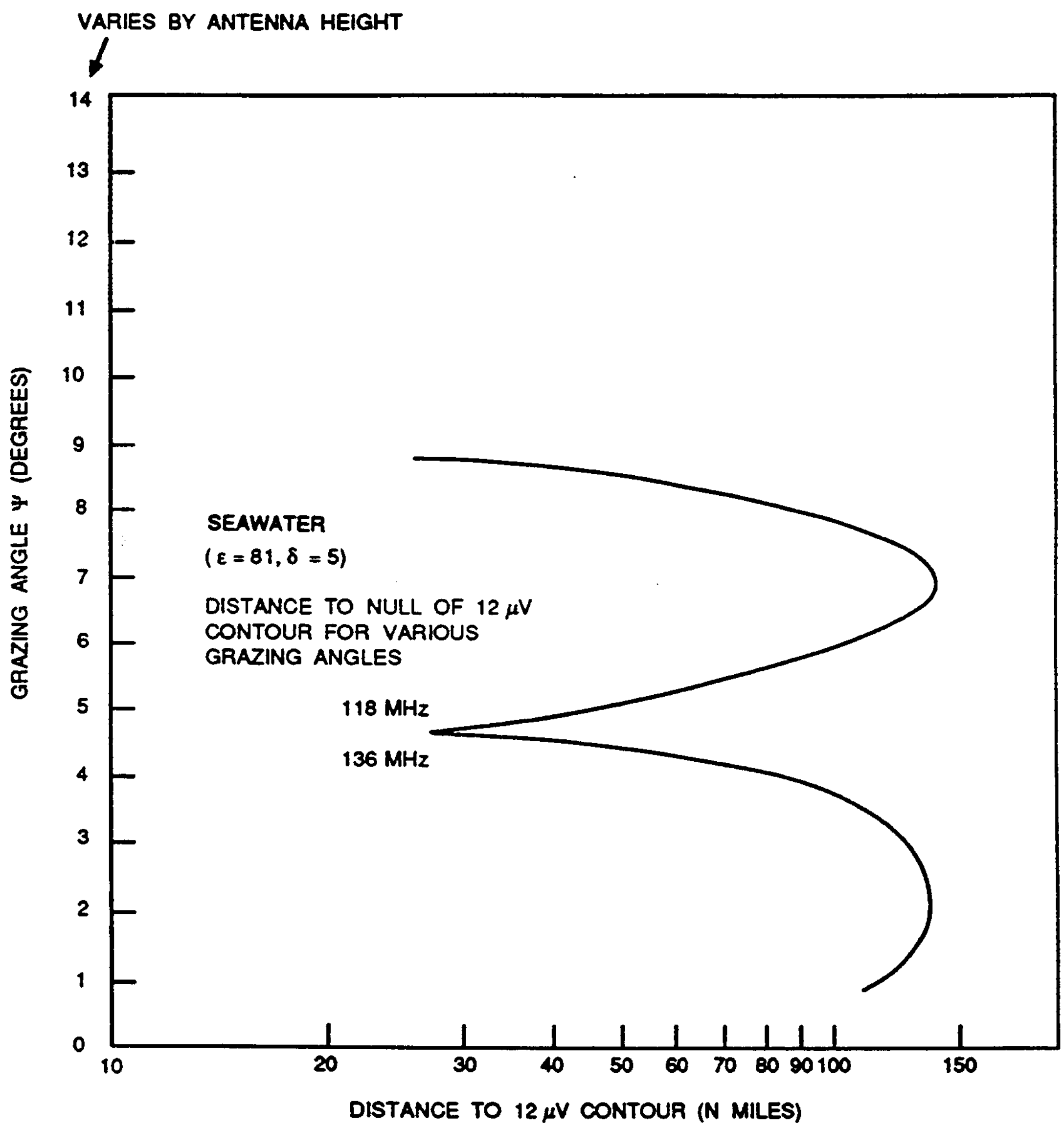


FIGURE 39. DISTANCE TO NULLS OF 12 uV CONTOUR FOR VARIOUS GRAZING ANGLES (SEAWATER)



4. **RENORMALIZATION TO OTHER VALUES.**

a. **Receiver Antenna Values.** The method presented in paragraph 3 has been described as if the ground antenna is a transmit antenna. If, instead, it is a receive antenna, the same method is applicable. However, to fully understand the process, one must visualize the graphs presented in a slightly different manner. Since the equations (which are used to prepare the graphs in this appendix) are not sensitive to the direction of propagation (i.e., air-to-ground or ground-to-air), figure 23, can be considered to be a contour of all points where an airborne transmitter (with a power output of 6 watts output from the coaxial transmission line feeding the antenna) would produce a 12 uV signal at the 50 ohm input to a ground receiver. Recall that the description for the ground transmitter case was that figure 23, presented the contour of all points where a ground-based transmitter (with a power output of 6 watts output from the coaxial transmission line feeding the antenna) would produce a 12 microvolt signal at the 50 ohm input to an airborne receiver.

b. **Receiver Antenna Coverage and Nulls.** In steps 2 and 4 of paragraph 3b of this appendix, low-angle coverage distances (R2) and distances to nulls (R4) are determined so that they may be plotted on the service volume graph described in step 1. These distances, R2 or R4 may be increased or decreased as the result of using different radiated powers from the transmit antenna (aircraft or ground). The ratio of the actual distance, R_{ACTUAL}, to the distance determined in step 2 or step 4 is given by:

$$\frac{R_{ACTUAL}}{R_{2,4}} = \sqrt{\frac{P_T}{6 \text{ watts}}}$$

where P_T is the transmit power (in watts) at the output from the coaxial transmission line feeding the transmit antenna. Thus, if P_T is to be 40 watts; then

$$\frac{R_{ACTUAL}}{R_{2,4}} = \sqrt{\frac{40}{6}} = 2.58$$

c. **Receiver Antenna Actual Range.** Therefore, the actual range is increased to 2.58 times the value determined in step 2 or 4. This new value can be plotted in the graph prepared in step 1 to see if it meets the requirements by being to the right (or above) the required service volume.

d. **Receiver Antenna Actual Values**. Note that if the actual values of P_T are identical to those assumed in the construction of the graphs (i.e., P_T = 6 watts), then this renormalization process is unnecessary since R_{ACTUAL} will equal R_2 or R_4.

5. **SAMPLE CALCULATIONS**.

a. **Example 1**.

(1) **Facility Nominal Assumptions**. An approach control facility is to be capable of receiving an aircraft signal up to an altitude of 25,000 feet and out to a distance of 70 statute miles at a frequency of 118 MHz. It has been determined that the soil in all azimuthal directions from the ground antenna is average, squelch settings on the receiver are set at 3 uV, a typical system signal margin of 12 dB is to be employed, and all aircraft with an RF output of 6 watts (rated transmitter power of 10 watts) from the coaxial transmission line feeding the transmit antenna.

(a) **Step 1 - Plot Values**. Using figure 25, plot the following values on rectangular graph paper for an aircraft altitude of 25,000 feet. Additional values are not required since the maximum service volume range is 70 miles. The resulting service volume is presented in Figure 40, Comparison Graph for Example No. 1.

Resulting Service Volume:

Ψ (Degrees)	Distance to Aircraft (miles)
13.2	20
10.6	25
8.8	30
7.5	35
6.5	40
5.8	45
5.2	50
4.6	55
4.2	60
3.8	65
3.5	70

(b) **Step 2 - Locate First Null**. Using figure 35 (average ground), locate the position of the first null of the contour for an antenna height of 50 feet. Find Ψ = 4.8 degrees for a frequency of 118 MHz.

NOTE: The minimum aircraft altitude above the site at 70 nautical miles, for 12 uV to the receiver from a ground antenna having a 50 foot elevation is 7,800 feet (0.72 degrees).

(c) **Step 3 - Locate Null Position**. Using figure 35 (average ground) locate a null position of 4.8 degrees and a frequency equal to 73 nautical miles.

(d) **Step 4 - Plot Ψ**. Plot Ψ= 4.8 degrees and R = 73 miles on figure 40.

(e) **Step 5 - Nominal Values**. Since the values assumed in this example are the same as those nominal values presented in paragraph 2, no renormalization is necessary.

(2) **Example 1 Evaluation**. In this example, if a frequency of 136 MHz were selected instead of 118 MHz, the requirement would not have been met. Figure 40 shows that at a frequency of 136 MHz, the grazing angle, Ψ= 4.2 degrees, and the distance to the first null is 58 miles. Under these conditions the service volume would be penetrated. In addition, if other antenna heights were attempted, they too would not have met the requirements at the 136 MHz. In this case, transmitter power, squelch settings, margins, or frequencies must be reevaluated.

b. **Example 2**.

(1) **Nominal Assumptions**. A high altitude en route communications antenna is to be located in the desert and operated on a frequency near 136 MHz. Coverage requirements are for a maximum altitude of 45,000 feet and a maximum distance of 175 miles. A ground transmitter rated at 50 watts (radiated power of 40 watts) is assumed, 3 uV squelch levels will be used on the receiver, and a system margin of 12 dB is assumed.

NOTE: 0.4 degrees at 175 nautical miles equals 24,000 feet above the site (if site is at 1,000 feet, then 25,000 feet AMSL).

(a) **Step 1 - Plot Service Volume**. Using figure 25, plot the service volume as shown in Figure 41, Comparison Graph for Example No. 2.

(b) **Step 2 - Coverage Limits**. From figure 27, the 0.4 degree lower limit is found to be satisfied out to a distance of 175 miles and 24,000 feet above the site using an antenna height of 150 feet with transmitter power of 50 watts. Thus, to meet the 110 mile

FIGURE 40. COMPARISON GRAPH FOR EXAMPLE NO. 1

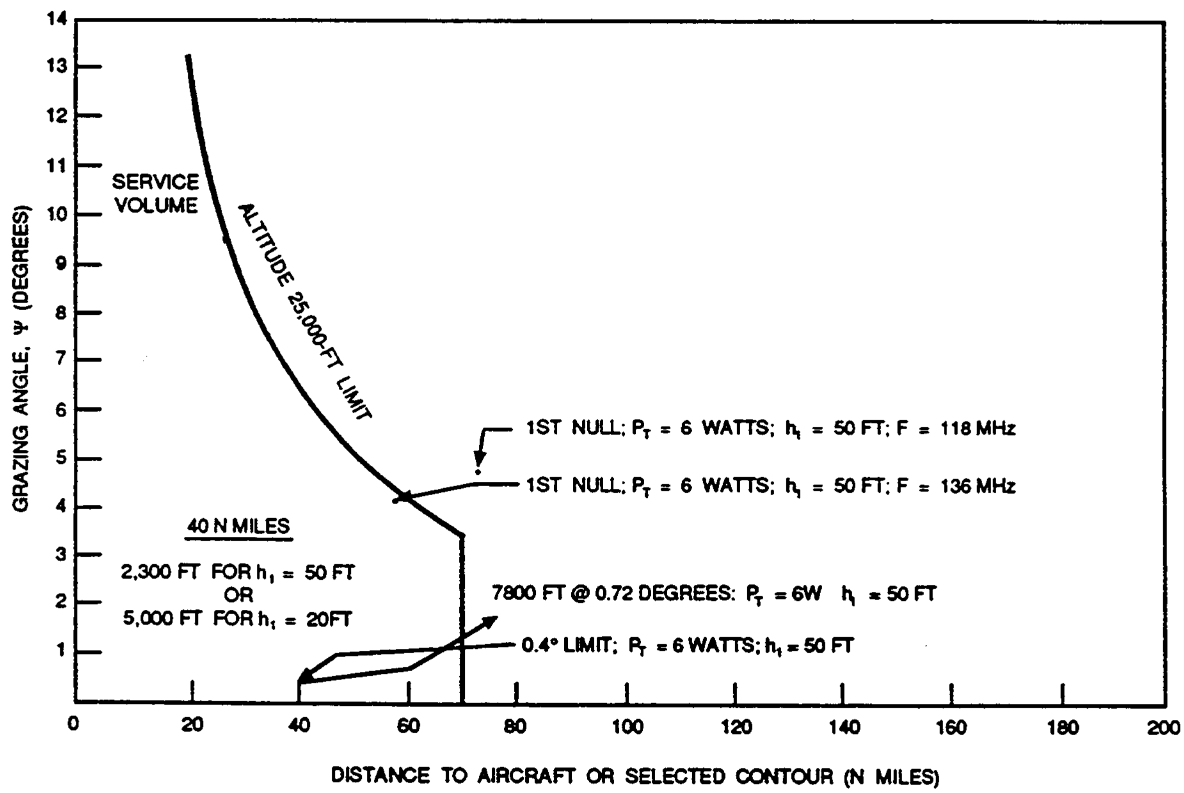
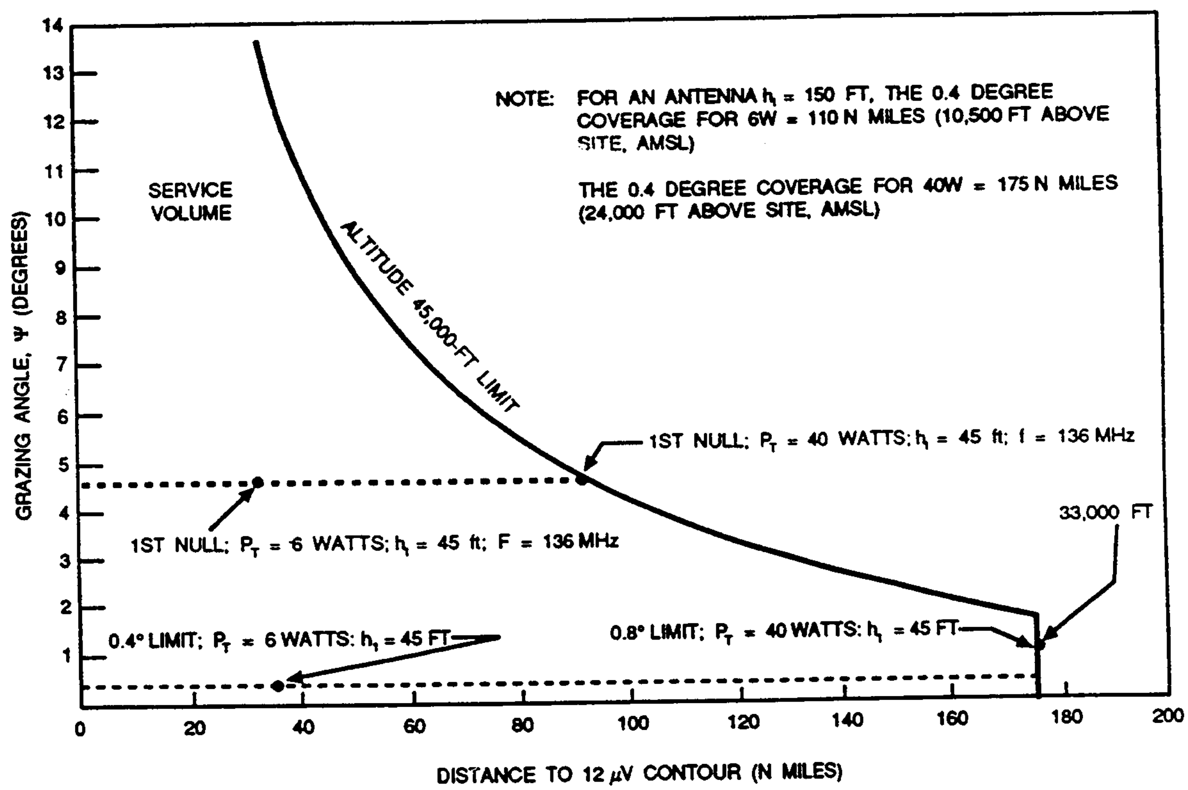


FIGURE 41. COMPARISON GRAPH FOR EXAMPLE NO. 2



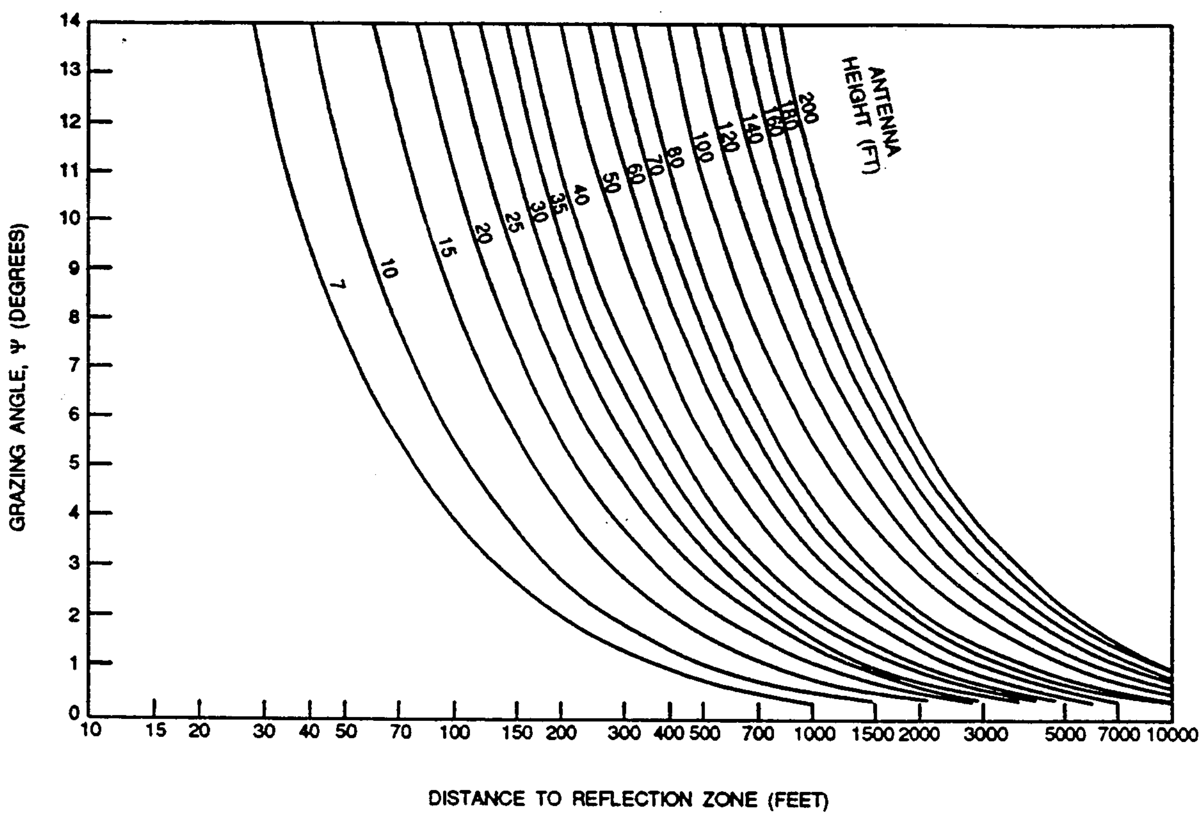
limit with coverage down to 0.4 degree, it is sufficient to satisfy the lower coverage limit with 6 watts at an antenna height of 150 feet.

(c) **Step 3 - Coverage Data**. See figure 41, for sample coverage data using an antenna height of 45 feet.

6. **REFLECTION ZONE FOR VERTICAL LOBING**. Figure 42, Reflection Zone for Vertical Lobing, is important in finding an optimum location for antennas. This figure shows the distance (in feet) to the reflection zone, and relates this distance to antenna height and grazing angle. Figure 42 should be used in conjunction with a reasonably accurate site map. The site map should show surface reflection conditions for a radius of about two miles from the proposed antenna site. It should show the elevation of large buildings, hills, forested areas, and water areas. A shift from land to water reflection has considerable effect on the lobe/null structure, especially seawater.

7.-10. **RESERVED**.

FIGURE 42. REFLECTION ZONE FOR VERTICAL LOBING



APPENDIX 7. PATTERN DISTORTION

1. **PURPOSE**. This appendix material is intended to augment the descriptions of pattern distortion discussed in chapter 6, section Six.

2. **GENERAL**. Pattern distortion is an undesired effect that can be due to any one of a number of causes. Distortion should be insignificant for a standard RCF antenna tower with all antennas and lightning air terminals separated by 8 feet or more. Of particular interest are distortions due to antennas that are in close proximity to a desired antenna and, as a result, couple to it. A typical cause of this distortion is shown in Figure 43, General Configuration for Omnidirectional Pattern Distortion. If the desired antenna is a transmit antenna, other antennas (or scatterers) close by receive the radiated energy and reradiate some or all of it. This reradiation adds with some phase relationship to the original radiation to distort the pattern from its original circular azimuth pattern to one which varies about the desired pattern (depending upon the aircraft's position). If the desired antenna is a receive antenna, both the antenna and the scatterer have approximately the same incident power density due to the direct path from the aircraft. However, the scattering antenna receives and reradiates this power and the reradiation is coupled to the desired antenna with the same result as in the transmit case. Since the communications link is degraded by the same amount whether the antennas under consideration are transmit or receive, the calculations to determine the magnitude of the pattern distortion will be described for the transmit case. The results would be the same for the receive case.

3. **VOLTAGE PATTERNS**.

a. **Antenna in Close Proximity**. A pair of antennas in close proximity (one acting as a transmit or receive antenna; the other acting as a scatterer or parasite of the other) produces a voltage pattern given by:

$$F(\theta) = [1 + A^2 + 2A \cos (kd \cos \theta + \phi)]^{1/2} \quad (1)$$

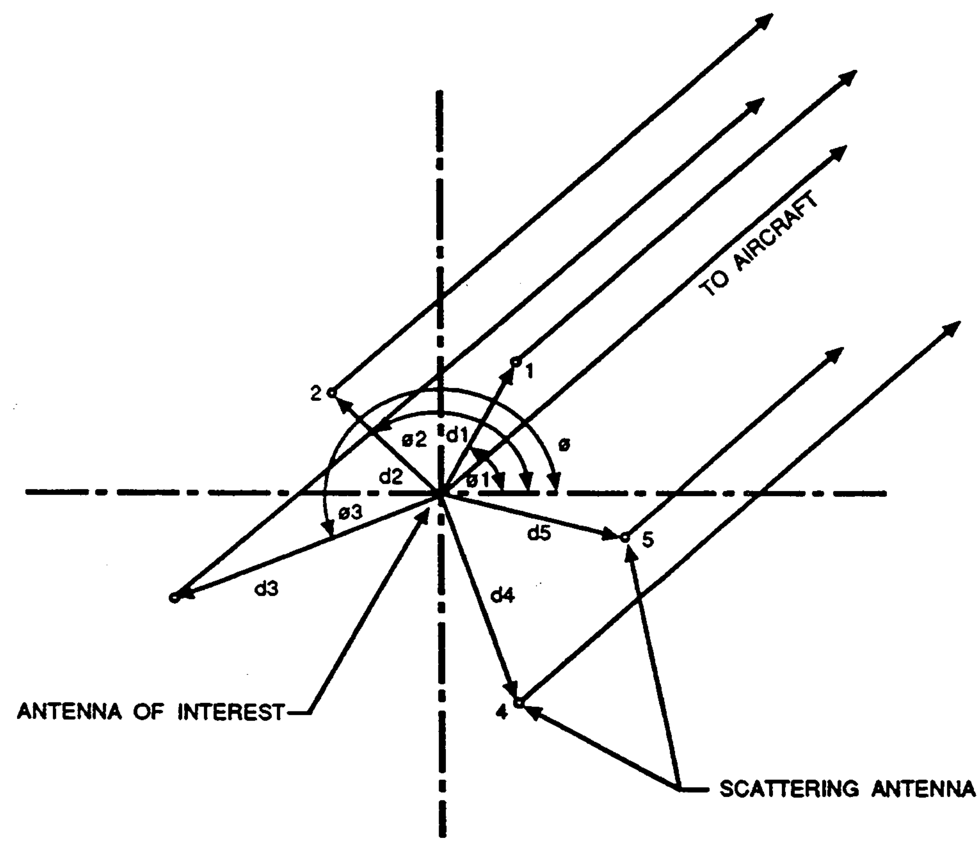
where:

$F(\theta)$ = the relative voltage produced at some point a great distance from the antennas

θ(theta) = the azimuth angle where the voltage is produced relative to an imaginary line drawn between two antennas

A = the amplitude produced in the direction due to the scattering antenna relative to the amplitude produced in the same direction due to the direct path from the desired antenna

FIGURE 43. GENERAL CONFIGURATION FOR OMNIDIRECTIONAL PATTERN DISTORTION



k = the propagation constant, $\frac{2\pi}{\lambda}$

d = the separation (in feet) between desired antenna and scattering antenna

ϕ(phi) = the phase of the reradiation relative to that of the desired antenna and scattering antenna

λ(lambda) = the free-space wavelength (in feet)

The parameter A is given by

$$A = \frac{\lambda G}{4 \pi d} \quad (2)$$

where:

G = the gain of the scattering antenna under consideration (see Table 16, Gain of Antennas and Objects causing Pattern Distortion)

The parameter θ is assumed to be the phase delay due to the propagation time between the desired antenna and the scattering antenna, that is

$$\phi = \frac{2 \pi d}{\lambda} \quad (3)$$

b. **Pattern Evaluation**. When a number of scatterers are in the vicinity of a desired antenna, the equation for the voltage pattern can be evaluated for each pair of antennas (comprising the desired antenna and a scatterer). The results at each azimuth angle are then multiplied together for the total pattern. Appropriate adjustments must be made for the respective orientations of the scatterers, as illustrated in figure 43. For example, if there are three scatterers, the total pattern is given by:

$$F(\theta) = F_1 \ (\theta - \theta_1) \ F_2 \ (\theta - \theta_2) \ F_3 \ (\theta - \theta_3) \quad (4)$$

where:

$F_1 \ (\theta - \theta_1)$ is the pattern due to the desired antenna and the first scatterer, using equation 1

$F2 \ (\theta - \theta_2)$ is the pattern due to the desired antenna and the second scatterer, using equation 1

$F3 \ (\theta - \theta_3)$ is the pattern due to the desired antenna and the third scatterer, using equation 1

TABLE 16. GAIN OF ANTENNAS AND OBJECTS CAUSING PATTERN DISTORTION

125 MHz (Nominal)

Type Of Reradiating Antenna Or Object	G_k
Dipole	1.64
VHF/UHF Collinear	2.9^n
7' - 8' Air Terminal	2.0^n

300 MHz (Nominal)

Type Of Reradiating Antenna Or Object	G_k
Dipole	2.10
VHF/UHF Collinear	3.90
7'- 8' Air Terminal	2.80^n

^{n} Developed Values

θ_1, θ_2, θ_3 are the angles of the various scatterers relative to the desired antenna and with respect to a reference direction (see figure 43)

c. **Intensity Pattern**. The voltage intensity pattern in decibels (dB) can then be found from the following equation:

$$F(\theta)\ dB = 20 \log_{10} F_1 (\theta - \theta_1) + 20 \log_{10} F_2 (\theta - \theta_2) + 20 \log_{10} F_3 (\theta - \theta_3) \qquad (5)$$

d. **Approximate Actual Pattern**. These equations represent an approximation to the actual pattern for the small values of A which can be expected, but the errors are negligible.

(1) **Intensity Values**. Values of voltage intensity less than unity (from equation 5) indicate distortion with the lowest value below unity representing the distortion exhibited by the evaluated antenna as a result of nearby antennas and radiating objects. The angle at which the distortion occurs is the angle at which a radiated or received signal may drop out or be missed. The maximum negative value of voltage intensity expressed in dB represents the total amount of pattern distortion.

(2) **Distribution Of Values**. The number and distribution of values in the radiation pattern are important for determining the effectiveness of a transmitted ground signal being heard by an aircraft and, conversely, a signal transmitted from an aircraft being received on the ground.

(a) **Antenna Placement Geometry**. For minimum pattern distortion, antenna placement geometry should avoid configurations where dips in radiation patterns coincide. Where dips in two patterns from three antennas coincide, pattern distortion doubles. Where dips in three patterns from four antennas coincide, pattern distortion triples.

(b) **Geometric Configurations**. Analyses of various computer runs for standard FAA antennas indicate no geometric configurations where pattern distortion values vary more than 1.5 dB from the values indicated in figure 19 of appendix 5.

(c) **Radiation Pattern Variation**. In general, the number of dips in a radiation pattern varies directly with the number of quarter-wavelengths separating the two antennas at the operating frequency of the antenna under investigation (for example, three quarter-wavelengths, three dips; and eight quarter-wavelengths, eight dips).

(d) **Number of Variations**. The greater the number of dips in the pattern, the more difficult it is to find geometric configurations that avoid dip coincidence. For this reason, the pattern distortion resulting from four standard VHF antennas arranged in a square is the same whether the spacing is 8 feet on a side or 16 feet on a side. These results are summarized in Table 17, Total Pattern Distortion for Four VHF Antennas Arranged in a Square.

e. **Arranging Three Antennas**. Arranging three antennas in an equilateral triangle configuration doubles the value of pattern distortion exhibited by a pair of antennas. This appears to be the case regardless of the length of the sides. Generally, this configuration should be avoided. An exception to this applies to the case where three antennas are mounted on a hexagonal tower. The greater separation obtained by mounting the antennas in alternate positions results in a lower value of pattern distortion than obtained from other arrangements.

f. **Hexagonal Tower Platforms**. Analysis of computer runs for standard antennas mounted on hexagonal towers indicates pattern distortion values varying from 0.6 dB for either of two VHF antenna positions filled. If UHF antennas are alternated with the VHF antennas, the values of pattern distortion are 1.5 dB for VHF antennas and less than 1.0 dB for UHF antennas.

g. **Empty Positions on Hexagonal Tower Platforms**. Empty positions on hexagonal tower platforms should be avoided. If five antennas are required, a spare should be added. If fewer than five are required, they should be distributed evenly around the tower. By using figure 19 of appendix 5, values of pattern distortion for any antenna on a hexagonal tower or ATCT cab roof can be estimated to within 1.5 dB of the value obtained from a complete analysis.

TABLE 17. TOTAL PATTERN DISTORTION FOR FOUR VHF ANTENNAS ARRANGED IN A SQUARE

Separation In Feet Between Two Antennas	Pattern Distortion (dB) From Figure-19 of Appendix 5	Total Pattern Distortion For Four Antennas Arranged In Square
8	1.2	1.2
12	0.8	1.6
16	0.6	1.2
32	0.3	0.6

APPENDIX 8. DETERMINATION OF RECEIVER DESENSITIZATION AND TRANSMITTER INTERMODULATION PRODUCT INTERFERENCE

1. **GENERAL**. The receiver desensitization and transmitter IM interference subjects are introduced in chapter 6. This appendix provides a more detailed approach to receiver desensitization and transmitter IM interference. Special worksheets and appropriate instructions have been developed for evaluating the extent of desensitization and IM interference from which the operating margin of safety can be determined.

a. **Receiver Desensitization**. Receiver desensitization is a function of the transmitter RF output power, system RF gains and losses, distance between transmit and receive antennas, and frequency separation between desired and undesired signals. Paragraph 2 describes the system RF parameters that contribute to receiver desensitization. Paragraph 3 of this appendix provides sample calculations to determine the level of receiver desensitization signals. Figures 9 and 10 of appendix 5 assist in determining the antenna separations that would be required to prevent or eliminate receiver desensitization effects. The most effective alternative is to keep transmitter to receiver antenna separation 120 feet or more.

b. **Transmitter Intermodulation (IM) Product Interference**. Transmitter IM product interference occurs when two or more frequencies produce IM products on a desired receive frequency. One method used to attenuate or eliminate IM product interference is by adequately separating transmitter and receiver antennas. A second and more common method of attenuating IM interference is to install ferrite isolators and tuned cavity filters (bandpass, notch or combiner cavities). Paragraph 4 describes the system parameters that contribute to transmitter intermodulation product interference. Paragraphs 5 and 6 provide sample calculations to determine the extent and level of IM product interference and the additional attenuation needed to reduce the IM product interference to an acceptable level. Curves in figures 11 through 16 of appendix 5 were developed to assist the field engineer in analyzing and minimizing interference effects.

2. **RECEIVER DESENSITIZATION**. A typical worksheet for evaluating the extent of desensitization or the operating margin of safety is presented in Table 19, Receiver Desensitization Worksheet. All system gain/loss parameters are also listed. Columns are provided for various frequency differences between desired and undesired signals. Frequency dependent parameters are inserted in the appropriate columns. Parameters that are not frequency dependent are represented by fixed values in each column. Parameters not applicable to a particular system are left blank. The signal level derived at the bottom of each column indicates whether a signal (at that particular

TABLE 19. RECEIVER DESENSITIZATION WORKSHEET

SYSTEM PARAMETERS		FREQUENCY SEPARATION BETWEEN DESIRED AND UNDESIRED SIGNAL											
		2MHz	1MHz	0.5MHz	0.2MHz	0.1MHz	90kHz	80kHz	70kHz	60kHz	50kHz	40kHz	30kHz
Transmitter Power Output Level	dBm												
Isolator Insertion Loss	dB												
Filter Insertion Loss	dB												
Coax Cable Attenuation (Transmit)	dB												
Antenna Gain (Transmit)	dB												
Space Attenuation	dB												
Collinear Antenna Isolation	dB												
Antenna Gain (Receive)	dB												
Coax Cable Attenuation (Receive)	dB												
Multi Receiver Coupling Attenuation	dB												
Filter Attenuation	dB												
Receiver Attenuation to Off-Freq.	dB												
Signal Level Input to Detector	dBm												
Reqd Sig Level Must be Below Reference Squelch Level	dB	-97.5	-97.5	-97.5	-97.5	-97.5	-97.5	-97.5	-97.5	-97.5	-97.5	-97.5	-97.5
Additional Atten. Reqd to Eliminate Destination	dB												
(1) VHF Receiver Off-Freq Atten.	dB	100	100	100	96	91	82	73	64	56	47	39	30
(1) UHF Receiver Off-Freq Atten.	dB	100	100	94	87	81	74	66	59	52	44	37	30

(1) These Average Values of Front End Attenuation Should be used in the Absence of Better Data

separation) has sufficient power to cause desensitization. A brief description of each listed parameter and other parameters follows:

a. <u>Transmitter Output Level</u>. The power level of the transmitter RF output at the RF output connector is in dBm. This value should be inserted in the worksheet (table 19) in each frequency separation column under consideration.

b. <u>Transmitter to Combiner Coax Cable Attenuation</u>. This is the section of coax feedlines between the transmitter and the isolator, if used, and the combiner. This may be a single section of coaxial cable, or if isolators are used, it may consist of several sections of coaxial cable.

c. <u>Isolator Insertion Loss</u>. Insert the appropriate value only if an isolator exists in the system. Typically, the value is 0.3 to 0.5 dB.

d. <u>Isolator Reverse Isolation</u>. Insert appropriate value only if an isolator exists in the system. The value is typically 30 to 40 dB.

e. <u>Filter Insertion Loss</u>. This may be a harmonic filter used with an isolator, or it may be a tuned cavity filter.

f. <u>Transmitter Combiner Cavity Insertion Loss</u>. Insert the transmit combiner cavity insertion loss. This loss will vary depending on the number of cavities used and the depth of the input and output coupling loops. The loss is typically 0.5 to 2.0 dB per cavity, depending on the coupling settings.

g. <u>Transmitter Combiner Transmitter/Transmitter Isolation</u>. This is the isolation, in dB, between transmitters that are connected to the transmitter combiner assembly.

h. <u>Combiner to Antenna Coaxial Cable Attenuation</u>. This is the section of coaxial cable between the transmitter combiner phasing cable common output connector and the antenna.

i. <u>Transmit Antenna Gain</u>. Insert the rated maximum gain of the transmit antenna in dB. See table 6 in appendix 3.

j. <u>Space Attenuation</u>. This is the free space path loss between the transmit and receive antennas. See figure 17 of appendix 5.

k. <u>Collinear Antenna Isolation</u>. Refer to the manufacturer's specifications (table 6 for TACO and APC antennas) or the results from measured tests.

l. **Receive Antenna Gain**. Insert the rated maximum gain of the receive antenna in dB. See table 6 in appendix 3.

m. **Antenna to Receiver Multicoupler Coaxial Cable Attenuation**. This is the section of the coaxial cable feedline between antenna and the receive antenna and the receiver frequency multiplexer. The attenuation value represents total losses between the antenna connector and the input connector of the receiver frequency multiplexer.

n. **Receiver Multicoupler Preselector Loss**. Insert the loss contributed by the receiver multicoupler preselector. The loss is typically 2.0 dB.

o. **Receiver Multicoupler Splitter Loss**. Insert the appropriate value for the receiver multicoupler amplifier gain or loss when it is applicable. A typical figure for an active amplifier type multicoupler is 18 dB gain for VHF and 17 dB gain for UHF.

p. **Receiver Multicoupler**. This is the loss due to splitting the signal for multiple receivers. A typical figure for eight multicoupler output loads is 10.5 dB loss.

q. **Receiver Filter Insertion Loss**. The IM product affecting the receiver is an on-frequency signal. Therefore, if a filter is used, the figure for insertion loss should be listed.

r. **Receiver Filter Attenuation**. Use only when a filter is installed or when checking attenuation value for interference elimination. Filter attenuation increases sharply as frequency separation increases. Refer to manufacturer's specification.

s. **Receiver Attenuation to Off-Frequency Signals**. Determine from published characteristics of the specific receiver or from measured receiver front-end attenuation characteristics.

t. **Signal Level Input to Detector**. RF power level (in dBm) present at the input to the receiver detector. This power level is determined by algebraically adding all gains and losses to the transmitter power output level.

u. **Additional Attenuation Required**. Additional attenuation required to eliminate possible receiver desensitization is the difference between the reference squelch level and the signal input to the detector. Typical squelch levels are 1.5 to 2.0 microvolts (-103.5 to -101 dBm).

3. **EXAMPLE OF RECEIVER DESENSITIZATION CALCULATIONS USING WORKSHEET**. VHF and UHF receivers used in FAA air-to-ground communications service are designed to specifications that call for 100 dB attenuation to receiver off-frequency signals of 0.5 MHz or greater from the desired receiver frequency. When the frequency difference between the interfering and desired signal becomes less than 0.5 MHz, the receiver's off-frequency input attenuation characteristics decrease rapidly.

a. **Receiver Desensitization Sample Calculation No. 1**.

(1) **Sample Worksheet**. The first sample calculation is illustrated using the Receiver Desensitization Worksheet (sample), Table 20. For example, a VHF transmitter output is 50 watts, there is a total of 2.5 dB coaxial cable loss, and an antenna gain of 1 dB. The receive antenna is spaced 80 feet distance from the transmit antenna, representing a space loss of 42 dB. The receive antenna has a 1 dB gain and a coaxial cable loss of 2.5 dB. The receiver off-frequency input attenuation figure is taken from the average values for VHF tabulated on the worksheet. Isolators, transmitter combiner cavities, and receiver multicouplers are not considered.

(2) The sample shows that 3.5/12.5 dB receiver (VHF/UHF) desensitization will occur at a frequency separation of 0.2 MHz for a squelch of 3 uV. For a squelch of 1.5 uV, the dB values go to 9.5/VHF and 18.5/UHF. The input bandpass characteristics of individual receivers may vary as much as 20 dB greater than the specification value shown, therefore, desensitization of 3.5 dB may occur in some receivers and not in others. In marginal cases, as given by this example, the actual bandpass characteristics of the particular receiver should be verified to obtain a more accurate value of receiver desensitization.

b. **Receiver Multicoupler Input Level Sample Calculation No. 2.** The active multicoupler amplifier is also subject to being overdriven. The second sample calculates the peak envelope power at the output of the multicoupler. Two example amplifiers used in modern active multicouplers are manufactured by TRW. The TRW VHF Type CA-2818 amplifier is overdriven when its output reaches the 30 dBm level. The TRW UHF Type CA-2800 amplifier is overdriven when its output reaches 24 dBm. The worst case occurs when all transmitters are keyed simultaneously and their RF carriers become inphase. The RCF configuration being considered below is equipped with four VHF transmitters combined with transmitter combiners and a single receiver connected to the output of a receiver multicoupler.

TABLE 20. RECEIVER DESENSITIZATION WORKSHEET (SAMPLE)

SYSTEM PARAMETERS		FREQUENCY SEPARATION BETWEEN DESIRED AND UNDESIRED SIGNAL											
		2MHz	1MHz	0.5MHz	0.2MHz	0.1MHz	90kHz	80kHz	70kHz	60kHz	50kHz	40kHz	30kHz
Transmitter Power Output Level	dBm	47	47	47	47								
Isolator Insertion Loss	dB												
Filter Insertion Loss	dB												
Coax Cable Attenuation (Transmit)	dB	2.5	2.5	2.5	2.5								
Antenna Gain (Transmit)	dB	1.0	1.0	1.0	1.0								
Space Attenuation	dB	42	42	42	42								
Collinear Antenna Isolation	dB												
Antenna Gain (Receive)	dB	1.0	1.0	1.0	1.0								
Coax Cable Attenuation (Receive)	dB	2.5	2.5	2.5	2.5								
Multi Receiver Coupling Attenuation	dB												
Filter Attenuation	dB												
(1) Receiver Attenuation to Off-Freq.	dB	100	100	100	96								
Signal Level Input to Detector	dBm	-98	-98	-98	-94								
Reqd Sig Level Must be Below Reference Squelch Level	dB	-97.5	-97.5	-97.5	-97.5	-97.5	-97.5	-97.5	-97.5	-97.5	-97.5	-97.5	-97.5
Additional Atten. Reqd to Eliminate Destination	dB												
(1) VHF Receiver Off-Freq Atten.	dB	100	100	100	96	91	82	73	64	56	47	39	30
(1) UHF Receiver Off-Freq Atten.	dB	100	100	94	87	81	74	66	59	52	44	37	30

(1) These Average Values of Front End Attenuation Should be used In the Absence of Better Data

(1)	Transmitter output power 10 watts..............	+40.0 dBm
(2)	Coaxial cable to combiner attenuation..........	- 0.3 dB
(3)	Combiner insertion loss........................	- 1.8 dB
(4)	Coaxial cable attenuation to antenna...........	- 0.8 dB
(5)	Transmit antenna gain..........................	0.0 dB
(6)	Free space path loss (80 feet).................	-42.0 dB
(7)	Receive antenna gain...........................	0.0 dB
(8)	Coaxial cable attenuation from antenna.........	- 0.8 dB
(9)	Multicoupler preselector loss..................	- 2.0 dB
(10)	Multicoupler splitter insertion loss...........	-10.5 dB
(11)	Multicoupler amplifier gain....................	<u>+18.0 dB</u>
(12)	Peak Envelope Power...(Results)...............	**-0.2 dBm**

(13) Peak Envelope Power at Multicoupler Output
-0.2 dBm = 0.00096 watts

(14) 0.00096 watts = $I^2R = IE$;

R = 50 ohms; I= 0.0044 A; E = 0.22 V

(15) P_{peak} = (No. of carriers)^2 x (1.41) 0.0044 x (1.41) 0.22
= watts

(16) With four carriers:

P_{peak} = 16 x 0.006 x 0.31 = 0.03 watts = 14.5 dBm

4. **<u>TRANSMITTER INTERMODULATION PRODUCT INTERFERENCE</u>**. Sample worksheets are provided in table 21 and paragraph 6 of this appendix as an aid in evaluating transmitter IM interference. All system gain/loss parameters that might appear in a communications system are listed in the figures. Columns are provided for various frequency separations from 0.1 MHz to 2.0 MHz. Those parameters not applicable to a particular system should be left blank. A brief explanation of each listed parameter and other parameters follows.

TABLE 21. TRANSMITTER INTERMODULATION PRODUCT INTERFERENCE PARAMETERS

SYSTEM PARAMETERS		FREQUENCY SEPARATION					
		2MHz	1MHz	0.5MHz	0.3MHz	0.2MHz	0.1MHz
Power Out (Tx #1)	dBm						
Isolator Insertion Loss	dB						
Filter Insertion Loss	dB						
Coax Cable Attenuation (Tx #1)	dB						
Antenna Gain (Tx #1)	dB						
Space Attenuation	dB						
Collinear Antenna Isolation	dB						
Antenna Gain (Tx #2)	dB						
Coax Cable Attenuation (Tx #2)	dB						
Filter Attenuation	dB						
Isolator Attenuation	dB						
IM Attenuation (Tx #2)	dB						
Isolator Insertion Loss	dB						
Filter Attenuation	dB						
Coax Cable Attenuation (Tx #2)	dB						
Antenna Gain (Tx #2)	dB						
Collinear Antenna Isolation	dB						
Space Attenuation	dB						
Antenna Gain (Rx)	dB						
Coax Cable Attenuation (Rx)	dB						
Filter Insertion Loss	dB						
Mult Receiver Coupling Attenuation	dB						
IM Product Level at Receiver Input	dBm						
IM Product Level Must be at Least 14dB Below Reference Squelch Level	dBm	-111.5	-111.5	-111.5	-111.5	-111.5	-111.5
Additional Attenuation Required to Eliminate Interference	dB						

Tx #1 MHz

Tx #2 MHz

a. **Transmitter No. 1 Output Level**. Power level of the transmitter No. 1 RF output at the output connector is in dBm. This value should be inserted in each frequency separation column under consideration. Ten watts equal 40 dBm.

b. **Transmitter No. 1 to Combiner Coaxial Cable Attenuation**. This is the section of coaxial feedline between the transmitter and the isolator, if used, and the combiner. It may be a single section of coaxial cable, or if isolators are used, it may consist of several sections of coaxial cable.

c. **Transmitter No. 1 Isolator Insertion Loss**. Insert appropriate value only if an isolator exists in the transmitter No. 1 system. Typically, value is 0.3 to 0.5 dB loss.

d. **Transmitter No. 1 Isolator Reverse Isolation**. Insert appropriate value only if an isolator exists in the transmitter No. 1 system. Typically, value is 35 to 40 dB isolation.

e. **Filter Insertion Loss**. This may be a harmonic filter used with an isolator, or it may be a tuned cavity filter.

f. **Transmitter No. 1 Combiner Cavity Insertion Loss**. Insert the transmitter combiner cavity insertion loss. This loss will vary dependent on the number of cavities used and the depth of the input and output coupling loops. See figures 45 and 46, typically 0.5 dB insertion loss per cavity.

g. **Transmitter No. 1 Combiner Transmitter/Transmitter Isolation**. This is the isolation, in dB, between transmitters that are connected to the transmitter No. 1 transmitter combiner assembly. See figures 45 and 46.

h. **Transmitter No. 1 Combiner to Antenna Coaxial Cable Attenuation**. This is the section of coaxial cable between the transmitter combiner phasing cable common output connector and the antenna.

i. **Transmitter No. 1 Antenna Gain**. Insert the rated maximum gain of the transmitter No. 1 antenna in dB. TACO and APC nondirectional vertical collinear antenna elements are rated at zero dB gain.

j. **Collinear Antenna Isolation**. Refer to the manufacturer's specifications (table 10 for TACO and APC antennas) or the results from measured tests.

k. **Space Attenuation**. This is the free space path loss between the two transmit antennas. See figure 17 of appendix 5.

FIGURE 45. SINGLE VHF TRANSMITTER COMBINER EIGHT-INCH ALUMINUM CAVITY INSERTION LOSS

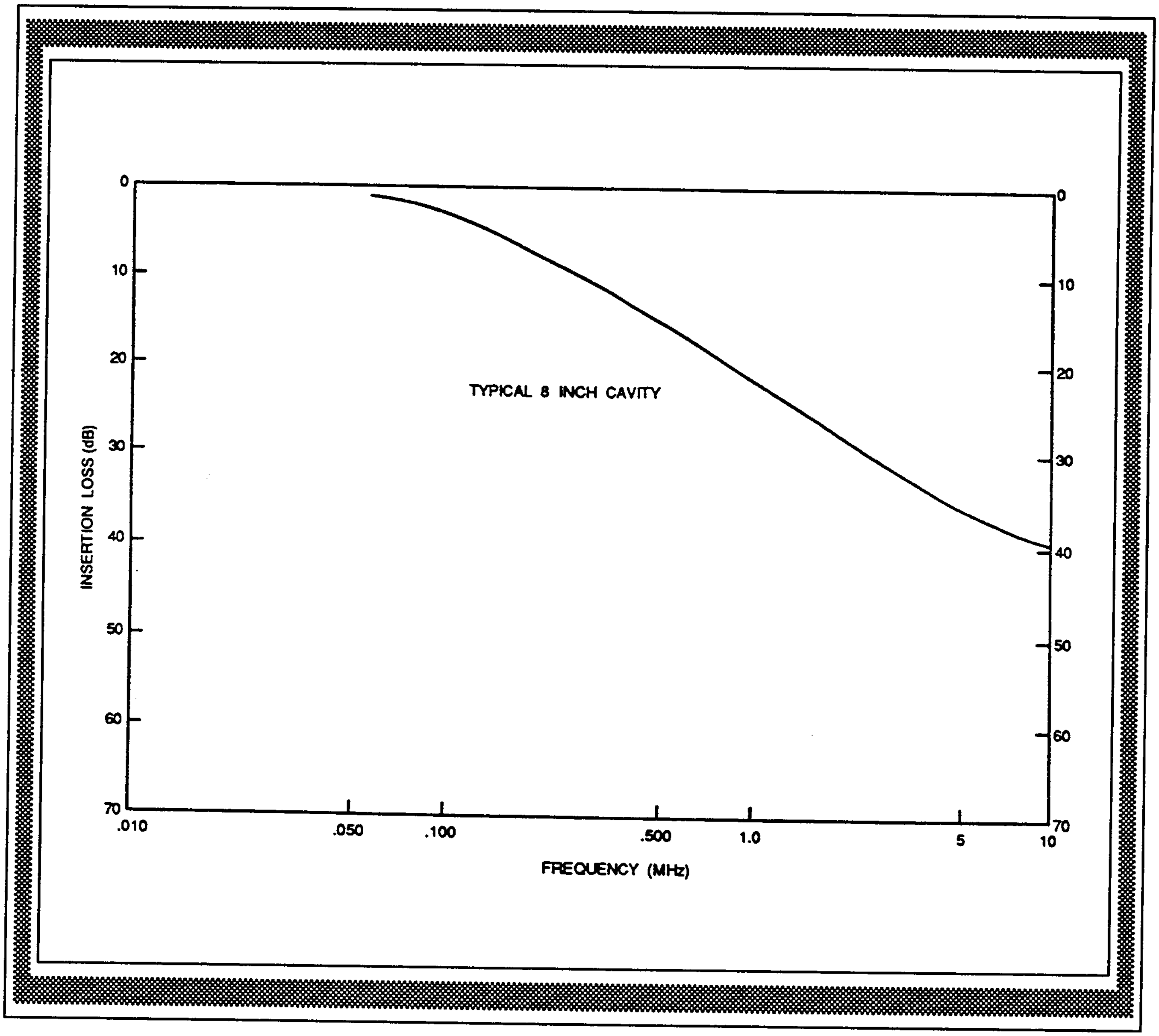
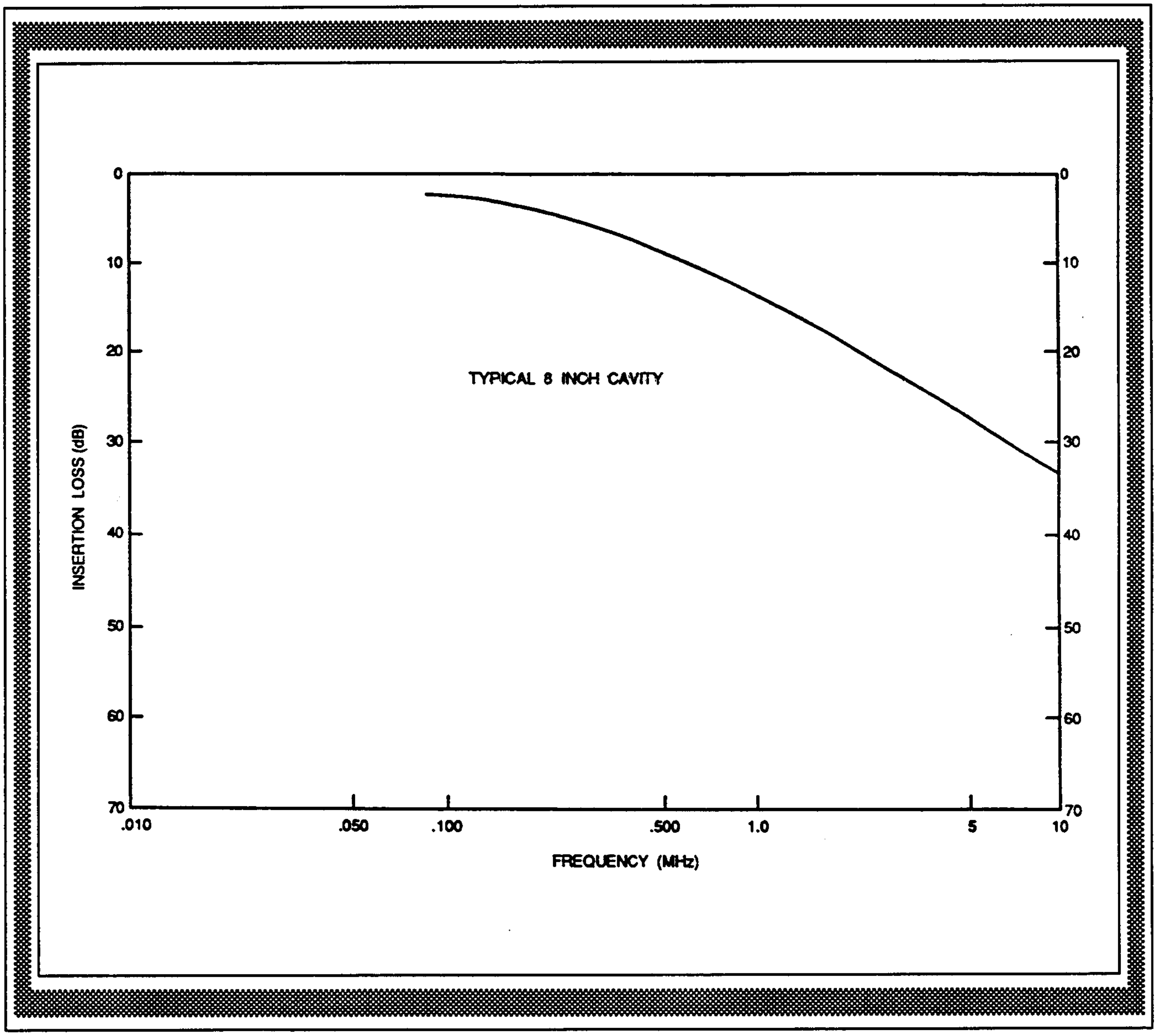


FIGURE 46. SINGLE UHF TRANSMITTER COMBINER EIGHT-INCH ALUMINUM CAVITY INSERTION LOSS



l. **Transmitter No. 2 Output Level**. This is the power level of the transmitter No. 2 RF output at the output connector in dBm. This value should be inserted in each frequency separation column under consideration.

m. **Transmitter No. 2 IM Product Attenuation**. This is a design characteristic of the transmitter. Depending on the transmitter used, the appropriate value can be found in Table 22, Transmitter Intermodulation Product Attenuation, for the frequency separation being considered. A typical figure for transmitter IM product attenuation is between 15 and 25 dB.

n. **Transmitter No. 2 to Combiner Coax Cable Attenuation**. This is the section of feedline between the transmitter No. 2 in which the IM products are being generated and the combiner. It may be a single section of coaxial cable, or if isolators are used, it may consist of several sections of coaxial cable.

o. **Transmitter No. 2 Isolator Reverse Isolation**. When a ferrite isolator is used, this is the attenuation presented to a signal passing through the isolator in the reverse direction. A typical value is 35 to 40 dB.

p. **Transmitter No. 2 Isolator Insertion Loss**. This is the same isolator referred to in subparagraph 4o of this appendix but the IM product signal is passing in the forward direction. A typical figure for insertion loss is 0.3 to 0.5 dB.

q. **Filter Attenuation**. The filter in this case is a resonant cavity in transmitter No. 2. The frequency of the incoming signal is offset from the resonant frequency of the cavity by the frequency difference between transmitters No. 1 and No. 2. The typical attenuation value is found from Table 23, Filter Device Attenuation.

r. **Transmitter No. 2 Combiner Cavity Insertion Loss**. Insert the transmit frequency combiner cavity insertion loss. This loss will vary dependent on the number of cavities used and the depth of the input and output coupling loops.

s. **Transmitter Combiner Transmitter/Transmitter Isolation**. This is the isolation, in dB, between transmitters that are connected to the frequency combiner assembly. See figures 45 and 46.

t. **Transmitter No. 2 Combiner to Antenna Coaxial Cable Attenuation**. This is the section of coaxial cable, in which the IM products are being generated, that is connected between the transmitter No. 2 frequency combiner phasing cable common output connector and the antenna.

TABLE 22. TRANSMITTER INTERMODULATION PRODUCT ATTENUATION

TRANSMITTER TYPE	FREQUENCY SEPARATION											
	5.0MHz	4.0MHz	3.0MHz	2.0MHz	1.0MHz	0.5MHz	0.3MHz	0.2MHz	0.1MHz			
AN/GRT-21 W/Amplifier (50 W)	68.5	65.0	60.5	55.0	47.0	33.0	22.0	22.0	22.0			
AN/GRT-21 (10 W Exciter)	21.0	21.0	21.5	22.0	22.0	21.5	21.5	21.0	21.0			
TV-35 (BW) (Carrier On)	65.0	63.0	61.0	57.0	49.0	43.3	33.0	24.0	24.0			
TV-35 (Carrier Off)	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	IM Caused by Two Other Transmitters		
(1) TV-36 (50 W)	70.0	68.0	63.5	53.0	46.0	33.0	25.0	23.0	23.0			
(1) AN/GRT-22 W/AMP (50 W)	65	60	55	47	35	27	22	22	22			
(2) AN/GRT-22 (10 W Exciter)	21	21	21.5	22	22	21.5	21.5	21	21			

(1) Extrapolated from data on typical cavities for UHF.
(2) Extrapolated from data on VHF Exciter.

TABLE 23. FILTER DEVICE ATTENUATION

EQUIPMENT TYPE	FREQUENCY SEPARATION								
	5.0MHz	4.0MHz	3.0MHz	2.0MHz	1.0MHz	0.5MHz	0.3MHz	0.2MHz	0.1MHz
Single Cavity 0.5 dB Insertion Loss	20.0	17.0	13.0	11.0	6.5	2.5	1.0	0.5	0.5
Single Cavity 1.0 dB Insertion Loss	26.0	24.0	22.0	18.0	13.0	7.0	5.0	1.0	1.0
Single Cavity 3.0 dB Insertion Loss	31.5	30.0	28.0	25.0	19.0	12.0	9.0	3.0	3.0
Dual Cavity 1.0 dB Insertion Loss	45.0	42.0	37.0	30.0	20.0	7.0	3.0	1.0	1.0
Dual Cavity 2.0 dB Insertion Loss	56.0	52.0	47.0	42.5	30.0	17.0	8.0	5.0	2.0
Dual Cavity 6.0 dB Insertion Loss	71.0	67.0	61.5	55.0	45.0	33.0	23.0	15.0	6.0
Triple Cavity 1.5 dB Insertion Loss	72.0	65.5	57.5	48.0	30.0	11.0	3.0	2.0	1.5
Triple Cavity 3.0 dB Insertion Loss		80.0	76.0	66.0	50.0	29.0	15.0	6.0	3.0
Triple Cavity 6.0 dB Insertion Loss				84.0	67.5	43.0	33.0	26.0	12.0
Ferrite Isolator 0.5 dB Insertion Loss	23	25	25	25	25	25	25	25	25
Harmonic Suppression Filter 0.1 dB Insertion Loss	← 43 dB or Better at 2nd Harmonic →								

u. <u>Transmitter No. 2 Antenna Gain</u>. Insert the rated maximum gain of the transmitter No. 2 antenna in dB. See table 10 for TACO and APC antennas.

v. <u>Collinear Antenna Isolation</u>. Refer to the manufacturer's specifications (table 10 for TACO and APC antennas) or the results from measured tests.

w. <u>Space Attenuation</u>. This is the free space path loss between transmitter No. 2 and the receive antenna. See figure 17, of appendix 5.

x. <u>Receive Antenna Gain</u>. Insert the rated maximum gain of the receive antenna in dB. See table 10 for TACO and APC antennas.

y. <u>Antenna to Receiver Multicoupler Coaxial Cable Attenuation</u>. This is the section of coaxial cable feedline between the receive antenna and the receiver multicoupler. The attenuation value represents total losses between the antenna connector and the input connector of the receiver multicoupler.

z. <u>Receiver Multicoupler Preselector Insertion Loss</u>. The receiver multicoupler preselector VHF and UHF bandpass preselector insertion loss is typically 2 dB.

aa. <u>Receiver Multicoupler Amplifier Gain/Loss</u>. Insert the appropriate value for the receiver multicoupler amplifier gain or loss when it is applicable. A typical value for an active amplifier type multicoupler is 18 dB gain for VHF and 17 dB gain for UHF.

bb. <u>Receiver Multicoupler Splitter Loss</u>. This is the loss due to splitting the signal for multiple receivers. A typical figure for eight multicoupler output loads is 10.5 dB loss.

cc. <u>Receiver Filter Insertion Loss</u>. The IM product affecting the receiver is an on-frequency signal. Therefore, if a filter is used, the figure for insertion loss should be listed.

dd. <u>Receiver Attenuation to Off-Frequency Signals</u>. Determined from published characteristics of the specific receiver or from measured receiver front-end attenuation characteristics. See figure 18, of appendix 5.

ee. <u>Signal Level Input to Detector</u>. RF power level (dBm) present at the input to the receiver detector. The power level is determined by algebraically adding all gains and losses to the transmitter power output level.

ff. **Additional Attenuation Required**. Additional attenuation required to eliminate possible receiver desensitization is the difference between the reference squelch level and the signal input to the detector.

gg. **IM Product Level at Receiver Input**. RF power level (dBm) of the interfering signal at the input to the receiver. This power level is determined by algebraically adding all gains and losses to the transmitting power output level.

hh. **Additional Attenuation Required**. To prevent interference, the IM product level must be less than -111.5 dBm to obtain a 14-dB desired-to-undesired signal ratio. If not, the additional attenuation is required to eliminate (or prevent) the interference between the IM product level (-115.5 dBm) and the IM level at the input to the receiver.

5. **CALCULATIONS (USING WORKSHEET) OF IM PRODUCT INTERFERENCE AT AN RCF COLLOCATED AT A VORTAC.**

a. **Transmitter Intermodulation Product Example No. 1**. The first example is based on the RCF that is collocated at a VORTAC site, illustrated in Table 24, Transmitter Intermodulation Product Interference Worksheet. See worksheet (sample) in table 25.

(1) Two 10-watt GRT-21 transmitters are connected through a transmitter combiner to a VHF antenna mounted on let-down pole that is located 60 feet from the center of the VORTAC antenna array.

(2) The receive antenna is mounted on a let-down pole located 120 feet from the transmit antenna. The receive antenna is 60 feet from the center of the VORTAC antenna array opposite the transmit antenna.

(3) The receiver is tuned to a frequency subject to third-order IM product interference ($2F_2 - F_1$.).

(4) The two transmit frequencies are 120.6 and 121.3 MHz, and the receive frequency 122.0 MHz.

b. **Antenna Spacings to Avoid IM Interference**. A transmit-to-transmit antenna separation of 120 feet requires a transmit-to-receive antenna separation of 450 feet. Refer to figure 12 of appendix 5. Since the transmit-to-receive antenna separation is actually 85 feet, the transmit-to-transmit antenna separation must be at least 650 feet. Since this distance is not practical at an RCF collocated at a VORTAC site for eliminating IM product interference, the worksheet is used to determine the additional attenuation required in order to maintain the antenna separation existing at the VORTAC.

When only two antennas are involved, the distortion value is found directly from the figure. If several antennas are involved, an approximate value for total distortion for the group can be found for any antenna by selecting the largest value found in figures 19 or 21 of appendix 5 for the closest antenna or vertical conducting object.

h. **Groups of Antennas**. Analysis of computer runs for groups of antennas spaced 8 feet apart in a rectangular or square matrix containing 16 or 20 antennas indicates worst case total pattern distortion values. These values are approximately twice that obtained from figure 19 of appendix 5 for two antennas spaced 8 feet apart.

i. **Reduction of Pattern Distortion**. Reduction of pattern distortion is achieved by installing antennas in a rectangular configuration having spacings of 12 feet by 16 feet. Pattern dip cancellations result in a total distortion value approximately equal to that obtained from figure 19 of appendix 5 for two antennas spaced 12 feet apart. Further reduction is achieved by increasing the spacing to 24 feet by 32 feet.

j. **Four Antennas**. An example of a computer analysis of four antennas arranged in a square is shown in Figure 44, Four Standard Antennas Arranged in a Square. The program was developed from equations 1 through 5 as cited in subparagraph 3b of this appendix.

(1) A_o is the antenna being observed for pattern distortion caused by the presence of A_1, A_2, and A_3.

(2) The computer output consists of three columns of figures, as shown in Table 18, Computer Generated Analysis of Horizonal Distortion. The first is the azimuthal reference angle in degrees. The second is the voltage intensity in the far field. The third is the voltage intensity (in dB) relative to an isotropic radiator.

(3) The composite antenna pattern for A_o is obtained by horizontal multiplication of the values in the voltage intensity columns (table 18) for each azimuth angle and converting the product into dB, or by adding the respective values in dB, as shown in the fourth column. The maximum negative values represent pattern distortion or dips below the value exhibited by an omnidirectional antenna.

(4) Pattern distortion for the composite radiation pattern caused by the presence of A_1, A_2 and A_3 occurs at 130 degrees and 320 degrees, and amounts equal to 1.1 dB. The value obtained from figure 19 of appendix 5 using an 8-foot separation is approximately 1.2dB.

4.-10. **RESERVED**

FIGURE 44. FOUR STANDARD ANTENNAS ARRANGED IN A SQUARE

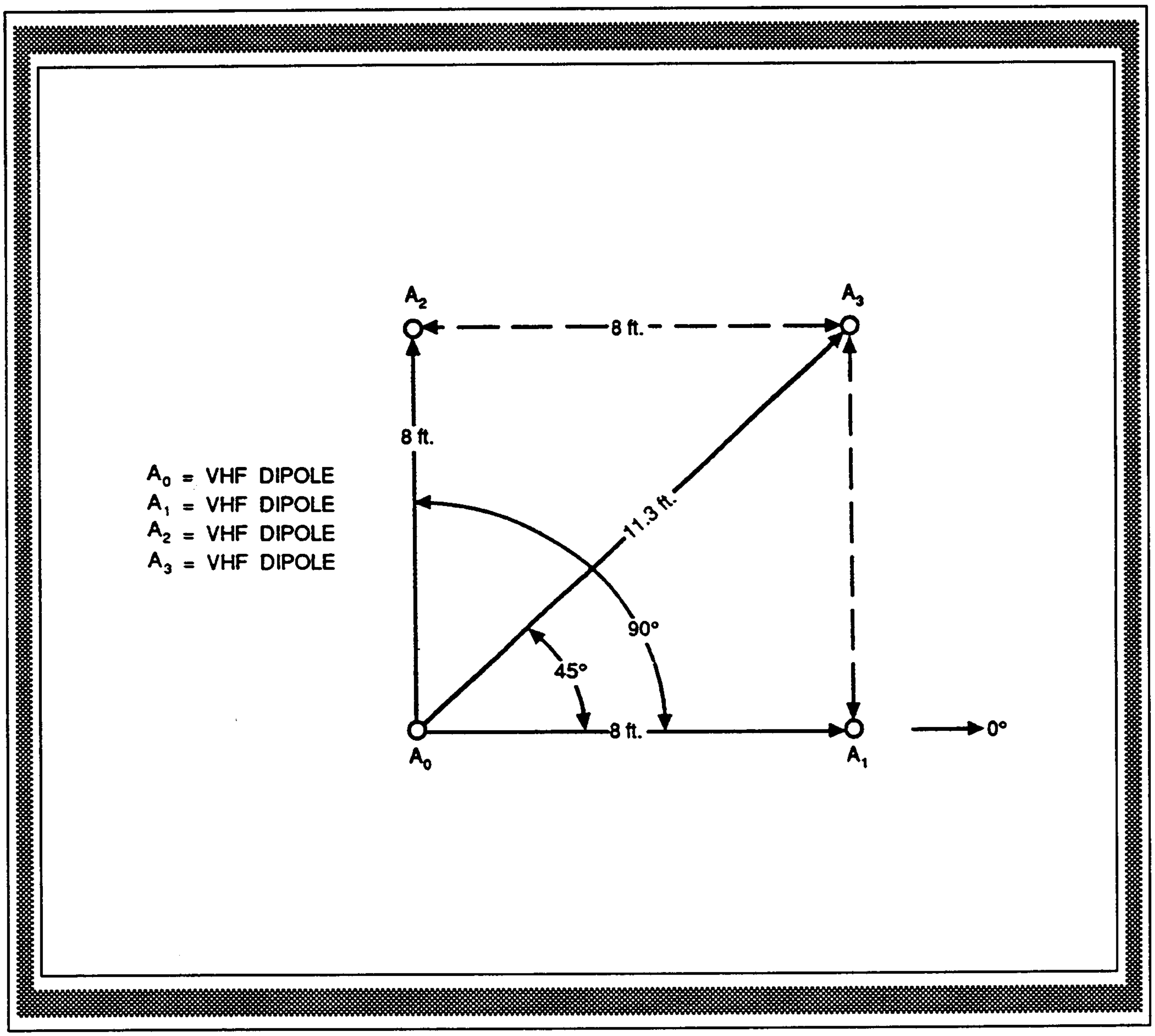


TABLE 18. COMPUTER GENERATED ANALYSIS OF HORIZONTAL DISTORTION

A0 To A1			A0 To A2			A0 To A3			
Gain (Rel) 1.64			Gain (Rel) 1.64			Gain (Rel) 1.64			Composite
Freq (MHz) 125			Freq (MHz) 125			Freq (MHz) 125			Antenna
Range (ft) 8.00			Range (ft) 8.00			Range (ft) 11.31			Pattern
Delta Theta (Deg) 0			Delta Theta (Deg) 90			Delta Theta (Deg) 45			Max. Neg.
	Distortion			Distortion			Distortion		Value is Pattern
AZ(Deg)	Rel	dB	AZ(Deg)	Rel	dB	AZ(Deg)	Rel	dB	Distortion
0	1.1279	1.05	0	1.1262	1.03	0	.9136	-.78	1.29
10	1.0523	.44	10	1.1278	1.04	10	.9330	-.60	.89
20	.9211	-.71	20	1.1265	1.03	20	.9974	-.02	.30
30	.8732	-1.18	30	1.1047	.86	30	1.0438	.37	.06
40	.9442	-.50	40	1.0426	.36	40	1.0632	.53	.40
50	1.0426	.36	50	.9442	-.50	50	1.0632	.53	.40
60	1.1047	.86	60	.8732	-1.18	60	1.0438	.37	.06
70	1.1265	1.03	70	.9211	-.71	70	.9974	-.02	.30
80	1.1278	1.04	80	1.0523	.44	80	.9330	-.60	.89
90	1.1262	1.03	90	1.1279	1.05	90	.9136	-.78	1.29
100	1.1278	1.04	100	1.0740	.62	100	.9983	-.01	1.65
110	1.1265	1.03	110	.9437	-.50	110	1.0878	.73	1.26
120	1.1047	.86	120	.8717	-1.19	120	1.0359	.31	-.02
130	1.0426	.36	130	.9215	-.71	130	.9165	-.76	-1.11
140	.9442	-.50	140	1.0180	.16	140	.9696	-.27	-.61
150	.8732	-1.18	150	1.0886	.74	150	1.0841	.70	.26
160	.9211	-.71	160	1.1201	.99	160	1.0465	.39	.67
170	1.0523	.44	170	1.1279	1.05	170	.9328	-.60	.88
180	1.1279	1.05	180	1.1285	1.05	180	.9212	-.71	1.38
190	1.0740	.62	190	1.1279	1.05	190	.9986	-.01	1.65
200	.9437	-.50	200	1.1201	.99	200	1.0624	.53	1.01
210	.8717	-1.19	210	1.0886	.74	210	1.0869	.72	.27
220	.9215	-.71	220	1.0180	.16	220	1.0908	.75	.20
230	1.0180	.16	230	.9215	-.71	230	1.0908	.75	.20
240	1.0886	.74	240	.8717	-1.19	240	1.0869	.72	.27
250	1.1201	.99	250	.9437	-.50	250	1.0624	.53	1.01
260	1.1279	1.05	260	1.0740	.62	260	.9986	-.01	1.65
270	1.1285	1.05	270	1.1279	1.05	270	.9212	-.71	1.38
280	1.1279	1.05	280	1.0523	.44	280	.9328	-.60	.88
290	1.1201	.99	290	.9211	-.71	290	1.0465	.39	.67
300	1.0886	.74	300	.8732	-1.18	300	1.0841	.70	.26
310	1.0180	.16	310	.9442	-.50	310	.9696	-.27	-.61
320	.9215	-.71	320	1.0426	.36	320	.9165	-.76	-1.11
330	.8717	-1.19	330	1.1047	.86	330	1.0359	.31	-.02
340	.9437	-.50	340	1.1265	1.03	340	1.0878	.73	1.26
350	1.0740	.62	350	1.1278	1.04	350	.9983	-.01	1.65
360	1.1279	1.05	360	1.1262	1.03	360	.9136	-.78	1.29

TABLE 24. TRANSMITTER INTERMODULATION PRODUCT INTERFERENCE WORKSHEET

SYSTEM PARAMETERS		FREQUENCY SEPARATION					
		2MHz	1MHz	0.5MHz	0.3MHz	0.2MHz	0.1MHz
TX #1 RF Output Power Level	dBm						
TX #1 To Combiner Coax Loss	dB						
TX #1 Isolator Insertion Loss	dB						
TX #1 Isolator Reverse Loss	dB						
Filter Insertion Loss	dB						
TX #1 Freq. Combiner Loss	dB						
TX #1 Freq. Comb. TX Loss	dB						
TX #1 Comb. to Ant. Coax Loss	dB						
TX #1 Antenna Gain	dB						
#1 Collinear Antenna Isolation	dB						
Space Attenuation (TX#1/TX#2)	dB						
TX #2 RF Output Power Level	dBm						
TX #2 IM Product Attenuation	dB						
TX #2 to Combiner Coax Loss	dB						
TX #2 Isolator Reverse Loss	dB						
TX #2 Isolator Insertion Loss	dB						
Filter Attenuation	dB						
TX #2 Freq. Combiner Loss	dB						
TX #2 Freq. Comb. TX/TX	dB						
TX #2 Comb. to Ant. Coax Loss	dB						
TX #2 Antenna Gain	dB						
#2 Collinear Antenna Isolation	dB						
Space Attenuation (TX #2/RX)	dB						
Receive Antenna Gain	dB						
Ant to Multicoupler Coax Loss	dB						
Multicoupler Preselector Loss	dB						
Multicoupler Gain/Loss	dB						
Multicoupler Splitter Loss	dB						
Receiver Filter Insertion Loss	dB						
*VHF RX Atten. to Off-Freq. Sig.	dB	100	100	100	98	96	91
*UHF RX Atten. to Off-Freq. Sig.	dB	100	100	94	90	87	81
IM Product Sig. Level at Rcvr.	dBm						
IM Product Level Must be at Least 14 dB Below Reference Squelch Level	dBm	-111.5	-111.5	-111.5	-111.5	-111.5	
Additional Attenuation Required to Eliminate Interference	db	18.0 dB					

*These average values of front end attenuation should be used in the absence of better data.

TABLE 25. TRANSMITTER INTERMODULATION PRODUCT INTERFERENCE WORKSHEET (SAMPLE)

SYSTEM PARAMETERS		FREQUENCY SEPARATION					
		2MHz	1MHz	0.5MHz	0.3MHz	0.2MHz	0.1MHz
TX #1 RF Output Power Level	dBm			40.0 dBm			
TX #1 To Combiner Coax Loss	dB			-0.3 dBm			
TX #1 Isolator Insertion Loss	dB						
TX #1 Isolator Reverse Loss	dB						
Filter Insertion Loss	dB						
TX #1 Freq. Combiner Loss	dB			-1.0 dBm			
TX #1 Freq. Comb. TX Loss	dB			-34.0 dBm			
TX #1 Comb. to Ant. Coax Loss	dB			-0.8 dBm			
TX #1 Antenna Gain	dB			0.0 dBm			
#1 Collinear Antenna Isolation	dB						
Space Attenuation (TX#1/TX#2)	dB						
TX #2 RF Output Power Level	dBm						
TX #2 IM Product Attenuation	dB			-22.0 dBm			
TX #2 to Combiner Coax Loss	dB			-0.3 dBm			
TX #2 Isolator Reverse Loss	dB						
TX #2 Isolator Insertion Loss	dB						
Filter Attenuation	dB						
TX #2 Freq. Combiner Loss	dB			-0.3 dBm			
TX #2 Freq. Comb. TX/TX	dB			-34.0 dBm			
TX #2 Comb. to Ant. Coax Loss	dB						
TX #2 Antenna Gain	dB						
#2 Collinear Antenna Isolation	dB						
Space Attenuation (TX #2/RX)	dB			-45.5 dBm			
Receive Antenna Gain	dB			0.0 dBm			
Ant to Multicoupler Coax Loss	dB			-0.8 dBm			
Multicoupler Preselector Loss	dB			-2.0 dBm			
Multicoupler Gain/Loss	dB			18.0 dBm			
Multicoupler Splitter Loss	dB			-10.5 dBm			
Receiver Filter Insertion Loss	dB			-93.5 dBm			
*VHF RX Atten. to Off-Freq. Sig.	dB	100	100	100	98	96	91
*UHF RX Atten. to Off-Freq. Sig.	dB	100	100	94	90	87	81
IM Product Sig. Level at Rcvr.	dBm						
IM Product Level Must be at Least 14 dB Below Reference Squelch Level	dBm	-111.5	-111.5	-111.5	-111.5	-111.5	
Additional Attenuation Required to Eliminate Interference	db	18.0 dB					

*These average values of front end attenuation should be used in the absence of better data.

c. **Transmitter IM Product Sample Calculation No. 1**. Enter all the system gain and loss parameters in the 1 MHz frequency separation column in Table 24, Transmitter IM Product Interference Worksheet. Enter the two transmit frequencies in the appropriate boxes at the bottom of the sheet. A dual cavity transmitter frequency combiner is used in the transmitter output circuit. The combiner attenuates the signal from transmitter No. 1. which enters transmitter No. 2, and then attenuates the IM product leaving transmitter No. 2.

(1) Transmitter #1 output power 10 watts...... +40.0 dBm

(2) Transmitter #1 to combiner coaxial loss... - 0.3 dB

(3) Combiner insertion loss.................. - 1.0 dB

(4) Combiner Tx/Tx isolation (path #1)
(figure 45, 4.5 MHz separation)......................... -34.0 dB

(5) Coaxial cable attenuation to antenna...... - 0.8 dB

(6) Transmit #2 IM product attenuation
(table 18, GRT-21, 1 MHz)............................. -22.0 dB

(7) Transmitter #2 to combiner coaxial loss... - 0.3 dB

(8) Combiner Tx/Tx isolation (Path #2)
(figure 45, 4.5 MHz separation)......................... -34.0 dB

(9) Transmit antenna gain..................... - 0.0 dB

(10) Free space path loss (120 feet)
(figure 17, appendix 5)................................ -45.5 dB

(11) Receive antenna gain..................... 0.0 dB

(12) Antenna to multicoupler coax loss......... - 0.8 dB

(13) Multicoupler preselector loss............. - 2.0 dB

(14) Multicoupler splitter insertion loss...... -10.5 dB

(15) Multicoupler amplifier gain............... +18.0 dB

(16) IM product level (Results)................ **93.5 dBm**

d. **IM Product Signal Level**. The algebraic sum of the above RF level gains and losses determines the IM product level at the input to the receiver (-93.5 dBm). Since the required IM product level is -111.5 dBm, an additional 18 dB attenuation is required to prevent, or eliminate, interference for the configuration under consideration. Different frequency separations can be investigated by filling in the appropriate columns of table 24 and proceeding as detailed in subparagraph 5b.

6. **CALCULATIONS OF IM PRODUCT INTERFERENCE AT A STAND-ALONE RCF USING WORKSHEET.**

a. **Transmitter Intermodulation Product Example No. 2.** The second example is based on a stand-alone RCF. See Figure 47, Typical Stand-Alone RCF Intermodulation Product Interference Calculation.

(1) Two 10-watt transmitters are connected to VHF antennas on towers separated by a diagonal distance of 113 feet.

(2) The receive antenna is mounted on a tower located 80 feet from either transmit antenna tower.

(3) The receiver is tuned to a frequency subject to third-order IM product interference ($2F_2 - F_1$).

(4) The two transmit frequencies are 120.6 MHz and 121.3 MHz, and the receive frequency is 122.0 MHz.

(5) Transmitter No. 1 (120.6 MHz) is connected to the lower element of the collinear antenna.

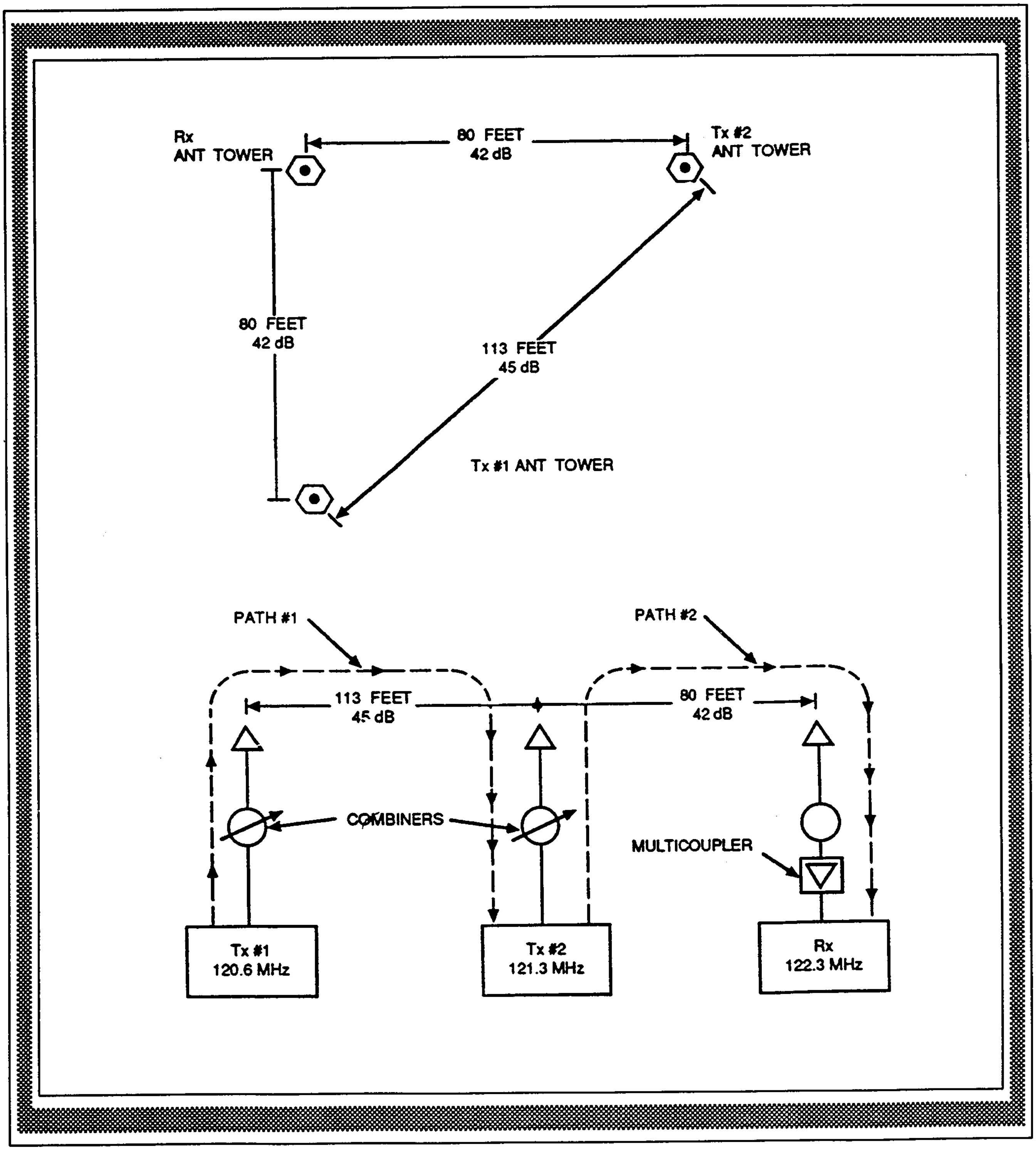
(6) Transmitter No. 2 (121.3 MHz) is connected to the upper element of the collinear antenna.

b. **Antenna Spacings to Avoid Intermodulation Interference.** A transmit-to-transmit antenna separation of 113 feet requires a transmit-to-receive antenna separation of 500 feet. Refer to figure 12 of appendix 5. Since the transmit-to-receive antenna separation is actually 80 feet, the transmit-to-transmit antenna separation must be at least 700 feet. Since this distance is not practical at an RCF site for eliminating IM product interference, the worksheet is used to determine the amount of additional attenuation required in order to maintain the antenna separation existing at the RCF.

c. **Transmitter IM Product Sample Calculation No. 2.** Enter all the system gain and loss parameters in the 1 MHz frequency separation column in Table 24, Transmitter IM Product Interference Worksheet. Enter the two transmit frequencies in the appropriate boxes at the bottom of the sheet. A dual cavity transmitter frequency combiner is used in the transmitter output circuits.

(1) Transmitter #1 output power 10 watts...... +40.0 dBm

FIGURE 47. TYPICAL STAND-ALONE RCF INTERMODULATION PRODUCT INTERFERENCE CALCULATION



(2) Transmitter #1 to combiner coaxial cable loss.- 0.3 dB

(3) Combiner insertion loss (path #1)............ - 1.0 dB

(4) Combiner bridging loss (path #1)............. - 0.5 dB

(5) Coax cable attenuation to antenna............ - 0.8 dB

(6) Free space path loss (113 feet)
(figure 17, appendix 5).................................... -45.0 dB

(7) Coaxial cable attenuation to combiner loss... - 0.8 dB

(8) Combiner xmtr/xmtr isolation (path #I)
(figure 45, 4.5 MHz separation)............................ -34.0 dB

(9) Combiner to transmitter #2 coaxial loss...... - 0.3 dB

(10) Transmitter #2 IM product attenuation
(table 22, GRT-21, 1 MHz).................................. -22.0 dB

(11) Transmitter #2 to combiner coaxial loss...... - 0.3 dB

(12) Combiner xmtr/xmtr isolation (path #2)
(figure 45, 700 kHz separation)............................ -34.0 dB

(13) Combiner bridging loss (path #2)............. - 0.5 dB

(14) Coax cable attenuation to antenna............ - 0.8 dB

(15) Transmit antenna gain (table 6).............. - 0.0 dB

(16) Free space path loss (80 feet)
(figure 17, appendix 5).................................... -42.0 dB

(17) Receive antenna gain (table 6)............... 0.0 dB

(18) Antenna to multicoupler coaxial loss......... - 0.8 dB

(19) Multicoupler preselector loss................ - 2.0 dB

(20) Multicoupler splitter insertion loss......... -10.5 dB

(21) Multicoupler amplifier gain.................. +18.0 dB

(22) IM product level..(Results)................. **-137.6 dBm**

d. **IM Product Signal Level**. The algebraic sum of the above RF level gains and losses determines the IM product level at the input to the receiver (-137.6 dBm).

e. **IM Product at Receiver Input**. No additional attenuation is required to prevent or eliminate IM interference for the configuration described, since the -137.6 dBm IM product level is 26.1 dB lower than the required -111.5 dBm IM product level. Note that in this situation the isolators are not required. Different frequency separations can be investigated by filling in the appropriate columns of table 8 and proceeding as detailed in subparagraph 6c.

f. **Additional Attenuation**. In the event that the applicable configuration requires additional attenuation, an alternate procedure that can be followed is to retune the frequency combiner cavities associated with transmitter No. 2. Referring to the transmitter No. 2 frequency combiner coupling adjustment, its associated insertion loss and frequency bandpass (changing from a 1 dB to a 2 dB insertion loss coupling (for two series connected combiner cavities)) will increase to a 1 MHz off-resonance loss of 10 dB. Note that this off-resonance loss is included twice in the IM product calculations, resulting in a total increase of 20 dB in IM product attenuation.

7. **SYSTEM GROUND AND HIGHER ORDER IM PRODUCTS**. If IM product interference greater than the fifth order is evident, recheck the RCF and host system grounding. Facilities that are near the sea coast have been found to have high orders of IM product interference that were corrected when the grounding system joints and connections were cleaned and rebonded.

8.-10. **RESERVED**.

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